CHAPTER 7

RESULTS AND DISCUSSION

FOR

EFFECTIVE INTERFACIAL AREAS

CHAPTER - 7

RESULTS AND DISCUSSION FOR INTERFACIAL AREAS

7.1.0 RESULTS AND DISCUSSION FOR WETTED SURFACE AREA (a_w) :

7.1.1 Critical analysis of data and mathematical modelling :

A data bank consisting of 100 data points covering 21 systems/variations reported in Table (5.1), could be used for analysing the effect of different variables on the values of a_w.

The parameters that affect the values of a_w are liquid flow rate (L), physical properties of solvent/absorption media like liquid density (ρ_L), viscosity (μ_L), surface tension (σ), packing size (d_p) and its dry area (a_t) and the affinity of the packing material for wetting by liquid which can be characterised by the critical surface tension (σ_c).

It is observed that the values of a_w increase with an increase in L and decrease with a decrease in a_t i.e. with an increase in d_p. With an increase in μ_L the values of a_w do decrease, however the effect appears to be quite small.

The data of Fujita et al. (10) and Hikita et al. (11) indicate that under otherwise identical conditions, by increasing the values of μ_L by two times or so, the value of a_w decreases marginally. With an increase in the value of ρ_L or σ_L, the values of a_w also decrease. This is expected in view of the lesser spreading of the liquid of higher surface tension on the packing surfaces than that of the liquid of lower surface tension. The data of Hikita et al. (11) and Onda et al. (12) confirm these observations. Further, with a decrease in the value of σ / σ_C, the values of a_w increase appreciably as could be seen from the data of Shulman et al. (8) and Mayo et al. (9).

Thus in order to correlate the data for a_w in terms of system parameters and hydrodynamic parameters, one can propose the following equation :-

$$a_w/a_t = f\ (L,\ a_t^{-1},\ \mu_L^{-1},\ \rho_L^{-1},\ \sigma^{-1},\ \sigma_C) \qquad (7.1)$$

With the help of dimensional analysis, these parameters can be grouped in terms of dimensionless numbers as per the following equation :-

$$a_w/a_t = C\ (Re)^{\alpha}\ (We)^{\beta}\ (Fr)^{\gamma}\ (\sigma / \sigma_C)^{\delta} \qquad (7.2)$$

It seems obvious that all the indices except that of (σ / σ_C) must be positive but of varying magnitudes to fulfil the parametric dependencies discussed earlier. Hence, the relevant dimensionless groups [calculated using the data reported in Table (5.1)] required for processing the data for a_w are tabulated in Table (7.1.1).

7.1.2 Statistical analysis for different correlations :

Processing of the data reported in Table (7.1.1) was done by three methodologies namely (i) Multiple Linear Regression. (ii)

Table – (7.1.1)

Results inclusive of processing parameters for wetted surface area (a_w)

No.	a_w m^2/m^3	Re	We $\times 10^5$	Fr $\times 10^5$	σ/σ_c	a_w/a_t exp.	a_w/a_t pred.	% err
1	79.1	40.48	369.480	81.027	1.510	0.460	0.469	-1.96
2	80.8	72.86	1197.153	262.535	1.510	0.470	0.571	-21.54
3	110.4	80.95	1477.919	324.107	1.510	0.642	0.592	7.82
4	103.2	3.76	6.868	6.970	1.510	0.279	0.241	13.61
5	135.8	9.41	42.927	43.563	1.510	0.367	0.328	10.70
6	166.9	18.82	171.758	174.302	1.510	0.451	0.414	8.33
7	36.8	12.11	22.098	2.166	1.510	0.320	0.292	8.73
8	46.0	30.27	138.112	13.540	1.510	0.400	0.397	0.71
9	57.5	60.54	552.613	54.175	1.510	0.500	0.501	-0.22
10	64.4	121.08	2210.452	216.700	1.510	0.560	0.632	-12.91
11	107.2	2.85	6.383	10.791	1.230	0.228	0.261	-14.44
12	165.0	5.70	25.532	43.163	1.230	0.351	0.329	6.21
13	164.6	12.79	67.368	67.962	1.000	0.445	0.424	4.68
14	188.3	17.63	127.970	129.099	1.000	0.509	0.472	7.20
15	253.4	32.80	443.231	447.141	1.000	0.685	0.582	15.07
16	266.4	39.54	644.149	649.832	1.000	0.720	0.619	13.97
17	88.8	1.64	3.258	2.733	0.833	0.240	0.276	-15.14
18	146.5	6.56	52.124	43.732	0.833	0.396	0.440	-11.09
19	168.4	9.85	117.279	98.398	0.833	0.455	0.504	-10.77
20	185.0	13.13	208.497	174.929	0.833	0.500	0.555	-11.01
21	55.5	1.79	2.096	0.509	0.833	0.279	0.256	8.20
22	68.1	4.27	11.872	2.881	0.833	0.342	0.343	-0.16
23	87.8	8.15	43.200	10.484	0.833	0.441	0.425	3.53
24	119.8	25.84	434.606	105.478	0.833	0.602	0.627	-4.08
25	69.3	0.47	0.175	0.067	0.472	0.210	0.217	-3.49
26	92.4	0.95	0.702	0.266	0.472	0.280	0.274	2.07
27	115.5	1.86	2.707	1.027	0.472	0.350	0.344	1.74
28	135.3	3.76	11.025	4.182	0.472	0.410	0.435	-6.15
29	148.5	4.68	17.041	6.464	0.472	0.450	0.468	-4.04
30	198.0	9.42	69.157	26.234	0.472	0.600	0.592	1.31
31	35.5	1.64	0.628	0.151	0.903	0.187	0.202	-8.07
32	41.2	3.24	2.457	0.590	0.903	0.217	0.254	-17.08
33	55.1	6.53	10.007	2.403	0.903	0.290	0.322	-10.87
34	71.3	16.37	62.766	15.074	0.903	0.375	0.437	-16.66
35	93.1	32.38	245.676	59.001	0.903	0.490	0.550	-12.24
36	34.2	0.82	0.172	0.038	0.833	0.180	0.169	6.36
37	38.0	1.64	0.680	0.151	0.833	0.200	0.212	-6.08
38	47.5	3.24	2.661	0.590	0.833	0.250	0.267	-6.68
39	57.0	6.53	10.840	2.403	0.833	0.300	0.338	-12.51
40	66.5	8.12	16.756	3.714	0.833	0.350	0.363	-3.75
41	79.8	16.37	67.997	15.074	0.833	0.420	0.459	-9.35
42	38.0	0.82	0.207	0.038	0.694	0.200	0.188	5.86
43	47.5	1.64	0.816	0.151	0.694	0.250	0.237	5.21
44	58.9	3.24	3.194	0.590	0.694	0.310	0.298	3.90
45	72.2	6.53	13.009	2.403	0.694	0.380	0.377	0.78
46	76.0	8.12	20.107	3.714	0.694	0.400	0.406	-1.40
47	98.8	16.37	81.596	15.074	0.694	0.520	0.513	1.35
48	43.7	0.82	0.272	0.038	0.528	0.230	0.222	3.30
49	57.0	1.64	1.074	0.151	0.528	0.300	0.280	6.69

Table - 7.1.1 (contd.)

No.	a_w m^2/m^3	Re	We x 10^5	Fr x 10^5	σ/σ_c	a_w/a_t exp.	a_w/a_t pred.	% err
50	72.2	3.24	4.202	0.590	0.528	0.380	0.352	7.39
51	91.2	6.53	17.116	2.403	0.528	0.480	0.445	7.21
52	98.8	8.12	26.456	3.714	0.528	0.520	0.479	7.86
53	117.8	16.37	107.364	15.074	0.528	0.620	0.606	2.26
54	28.5	0.44	0.154	0.033	0.861	0.150	0.163	-8.58
55	34.2	0.88	0.616	0.130	0.861	0.180	0.205	-14.16
56	50.9	1.72	2.378	0.503	0.861	0.268	0.258	3.84
57	57.0	4.39	15.406	3.258	0.861	0.300	0.353	-17.52
58	76.0	8.71	60.746	12.846	0.861	0.400	0.444	-10.94
59	85.1	13.00	135.371	28.627	0.861	0.448	0.508	-13.30
60	30.4	0.19	0.137	0.029	0.917	0.160	0.155	3.00
61	35.2	0.39	0.548	0.117	0.917	0.185	0.196	-5.85
62	52.3	0.78	2.194	0.468	0.917	0.275	0.247	10.16
63	58.9	1.94	13.711	2.924	0.917	0.310	0.336	-8.37
64	65.6	2.31	19.509	4.161	0.917	0.345	0.356	-3.31
65	72.2	2.91	30.849	6.579	0.917	0.380	0.385	-1.29
66	77.9	3.85	54.061	11.529	0.917	0.410	0.423	-3.14
67	85.5	5.75	120.474	25.693	0.917	0.450	0.484	-7.49
68	26.4	0.28	0.215	0.020	0.833	0.200	0.174	12.83
69	33.0	0.56	0.861	0.080	0.833	0.250	0.220	12.02
70	52.8	2.79	21.520	1.996	0.833	0.400	0.377	5.65
71	54.1	5.54	84.853	7.871	0.833	0.410	0.475	-15.86
72	114.1	0.86	0.802	1.880	1.098	0.195	0.194	0.64
73	155.0	1.79	3.440	8.065	1.098	0.265	0.247	6.66
74	175.5	2.59	7.215	16.916	1.098	0.300	0.280	6.64
75	189.5	3.45	12.827	30.072	1.098	0.324	0.308	4.80
76	200.7	4.28	19.757	46.319	1.098	0.343	0.332	3.32
77	136.9	0.95	1.168	1.880	0.754	0.234	0.243	-4.05
78	181.4	1.96	5.010	8.065	0.754	0.310	0.311	-0.27
79	204.8	2.84	10.509	16.916	0.754	0.350	0.352	-0.55
80	265.0	4.71	28.777	46.319	0.754	0.453	0.417	8.01
81	169.6	0.47	1.228	1.990	0.738	0.290	0.248	14.59
82	201.8	0.98	5.270	8.537	0.738	0.345	0.316	8.34
83	231.1	1.41	11.053	17.906	0.738	0.395	0.358	9.36
84	250.4	1.89	19.650	31.833	0.738	0.428	0.394	7.87
85	264.4	2.34	30.266	49.032	0.738	0.452	0.424	6.21
86	105.3	0.38	0.668	1.635	1.230	0.180	0.179	0.77
87	140.4	0.79	2.866	7.016	1.230	0.240	0.228	4.99
88	162.6	1.15	6.012	14.716	1.230	0.278	0.258	7.13
89	187.2	1.53	10.688	26.161	1.230	0.320	0.284	11.14
90	186.0	1.90	16.462	40.295	1.230	0.318	0.306	3.87
91	96.5	0.09	0.622	1.416	1.230	0.165	0.176	-6.72
92	114.1	0.18	2.667	6.074	1.230	0.195	0.225	-15.28
93	143.3	0.27	5.594	12.740	1.230	0.245	0.255	-3.89
94	158.0	0.35	9.944	22.648	1.230	0.270	0.280	-3.82
95	166.7	0.44	15.317	34.884	1.230	0.285	0.301	-5.75
96	99.5	0.26	0.619	1.440	1.246	0.170	0.175	-3.06
97	134.6	0.53	2.655	6.181	1.246	0.230	0.224	2.75
98	152.1	0.77	5.569	12.964	1.246	0.260	0.253	2.60
99	163.8	1.02	9.900	23.047	1.246	0.280	0.279	0.39
100	175.5	1.27	15.248	35.498	1.246	0.300	0.300	0.00

Optimization by the DSC - Powell algorithm and (iii) Optimization by the modified simplex algorithm of Nelder and Mead. The values of % E_{avg}, % E_{abs} and % S_{dev} were calculated for each methodology and also for different regression steps in each methodology. The results obtained by these three methodologies are reported in Table (7.1.2) and are discussed herewith.

CASE I : Multiple linear regression using the numerical methods of Gauss Jordan and Gauss Seidel, gave practically comparable statistical analysis as could be seen from the regression steps (1) to (3), wherein % E_{avg} was in the range of + 0.78 to -1.289 and % E_{abs} and % S_{dev} were of the order of 7 and 3.4 respectively.

CASE II : It was observed that using the DSC - Powell algorithm of optimization by changing the direction of search sequence, or by prefixing the values of indices of different numbers (except, that of 'We') did not alter the statistical analysis appreciabily as could be seen from the regression steps (4) to (9), exception being the regression step (6). The values of % E_{avg}, % E_{abs} and % S_{dev} remained in the ranges of (-1.0 to -1.99), (8.18 to 8.38) and (3.81 to 3.89) respectively. (This aspect has been discussed in detail elsewhere wherein statistical analysis does get affected considerably).

CASE III : Using optimization technique - the modified simplex algorithm of Nelder and Mead, by performing regressions as per steps (10 to 18) with relevant details mentioned therein, yielded the following equation :-

$$a_w/a_t = 1.431\ (Re)^{0.0014}\ (We)^{0.165}\ (Fr)^{0.002}\ (\sigma / \sigma_c)^{-0.442} \quad (7.3)$$

Table – (7.1.2)

Statistical analysis for different correlations of a_w

Correlation Structure : $a_w / a_l = C . Re^{\alpha} . We^{\beta} . Fr^{\gamma} . (\sigma / \sigma_c)^{\delta}$.

No.	C	α	β	γ	δ	% E_{avg}	% E_{abs}	% S_{dev}

Case 1 : – Multiple Linear Regression

Numerical Method : Gauss Jordan algorithm.

1	1.298	5.48E-05	0.145	0.011	-0.464	-1.289	7.114	3.43

Numerical Method : Gauss Seidel algorithm.

Convergence criteria $\varepsilon = 0.001$

2	1.22	0.009	0.139	0.0124	-0.474	1.11	7.088	3.44

Convergence criteria $\varepsilon = 0.0001$

3	1.27	0.003	0.142	0.013	-0.464	0.78	7.058	3.42

Case 2 :– Optimisation by the D S C – Powell algorithm.

Initialisation were based on arbitary guesses of indices, α β, γ, δ, and C were fed as 0.002, 0.18, 0.002, 0.4, 1.6.(Clue for guesses were taken from the values obtained in previous steps)

Direction of search sequence α, β, δ, γ, C. respectively.

4	1.4176	0.0014	0.165	0.001	-0.589	-1.56	8.25	3.84

Initialisation based on values of indices obtained in step no. 4. However α, value fed as 0.0014.

5	1.4176	0.0014	0.165	0.0015	-0.588	-1.09	8.16	3.82.

β value arbitarily fed as 0.14 and statistics of error recorded.

6	1.4176	0.0014	0.14	0.0015	-0.588	27.44	27.66	4.78.

Direction of search sequence changed to C, β, δ, α, γ. Initialisation as in step no 5.

7	1.433	0.0014	0.1653	0.002	-0.585	-1.59	8.18	3.81.

Table - 7.1.2 (contd.)

No.	C	α	β	γ	δ	% E_{avg}	% E_{abs}	% S_{dev}
Direction of search sequence changed to δ, C, β, α, γ. Initialisation as in step no. 5.								
8	1.431	0.0014	0.1653	0.002	-0.595	-1.92	8.38	3.89.
Direction of search sequence changed to β, C, δ, α, γ. Initialisation as in step no. 5.								
9	1.432	0.0014	0.165	0.002	-0.5947	-1.99	8.38	3.87.

Case 3 : - Optimisation by the Modified Simplex algorithm of Nelder and Mead

All parameters are iterated, base values as obtained from step no 3. Each indice value perturbed 50 % at a time.

10	1.425	0.001	0.1637	0.0031	-0.60	1.368	8.27	3.88.
α value fixed as 0.0014. Other parameters iterated as in step 10.								
11	1.406	0.0014	0.163	0.0024	-0.589	1.51	8.197	3.836.
α and δ values fixed as 0.0014 and -0.442. Other parameters iterated as in step 11.(Discussed in details later)								
12*	1.431	0.0014	0.165	0.002	-0.442	-0.45	7.04	3.29.
C fixed as 1.08 as obtained in the case of effective interfacial areas for physical absorpyion. Other parameters iterated as in step 10.								
13	1.08	0.024	0.134	0.0057	-0.434	0.966	7.11	3.51.
C fixed as 1.081, δ fixed as -0.442. Other parameters iterated as in step no. 10.								
14	1.08	0.010	0.1346	0.0039	-0.442	1.94	7.39	3.64.
C fixed as 1.08 and γ fixed as 0.002. Other parameters iterated as in step no. 10.								
15	1.08	0.023	0.1375	0.002	-0.445	0.44	7.23	3.56.
C, γ, δ fixed as 1.08, 0.002,-0.442 respectively. Other parameters iterated as in step no 10.								
16	1.08	0.019	0.1386	0.002	-0.442	1.94	7.39	3.64.

Table - 7.1.2 (contd.)

No.	C	α	β	γ	δ	% E_{avg}	% E_{abs}	% S_{dev}
C, α, γ, δ fixed as 1.08, 0.099, 0.002, -0.442 respectively. Only β iterated as in step no. 10.								
17	1.081	0.099	0.144	0.002	-0.442	2.95	11.78	6.04.
C, β, γ, δ fixed as 1.08, 0.22, 0.002, -0.442 respectively. Only α is iterated as in step no 10.								
18	1.08	0.198	0.22	0.002	-0.442	37.01	42.2	10.0.

Explainatory note :-

1 % E_{avg} is the percentage average error defined as follows :-

$$\% E_{avg} = \frac{1}{n} \left[\sum \frac{a_{exp} - a_{pred}}{a_{exp}} \right] * 100$$

2. % E_{abs} is the percentage absolute error defined as follows :-

$$\% E_{abs} = \frac{1}{n} \left[\sum \left| \frac{a_{exp} - a_{pred}}{a_{exp}} \right| \right] * 100$$

3. % S_{dev} is the percentage standard deviation of errors defined as follows

$$\% S_{dev} = \left[\sqrt{\frac{S_t}{n - 1}} \right] * 100$$

where S_t is the sum of residuals between the individual error and the mean of the error i.e , $S_t = \Sigma (\varepsilon_i - \bar{\varepsilon})^2$ and $\bar{\varepsilon} = (\Sigma \varepsilon_i)/ n$.

Note : The values of indices in the finalised generalised correlation are as per regression step marked by (*)

For obtaining the equation (7.3), regression was performed as per step (12) and the values of % E_{avg}, % E_{abs} and % S_{dev} were -0.45, 7.04 and 3.29 respectively. In equation - (7.3) the values of indices of all the dimensionless numbers inclusive of proportionality constant are such that the correlation under consideration predicts the values of a_w with the least amount of error.

In the regression step (17), all the indices except that of Weber number (We) were prefixed to C = 1.08, α = 0.099, γ = 0.002 and δ = - 0.442 (These indices were obtained for a generalised correlation which had been developed for predicting the values of a_p/a_t at a later stage) and regression was performed to optimize the power of Weber number (We). This methodology resulted in the following correlation having the statistical analysis as % E_{avg} = 2.95, % E_{abs} = 11.78 and % S_{dev} = 6.04 :-

$$a_w/a_t = 1.081\ (Re)^{0.099}\ (We)^{0.144}\ (Fr)^{0.002}\ (\sigma / \sigma_c)^{-0.442} \qquad (7.4)$$

The data fit of a_w by equation (7.4) is expected to be to some extent inferior than the data fit of a_w by equation (7.3) as could be seen from the statistical analysis of both the equations. However, this equation could also be considered as a satisfactory correlation for predicting the values of a_w. It is interesting to observe that all the indices of different groups in equation (7.4) which correlates data on a_w and that equation (7.7) (developed later on) which correlates data on a_p are identical except the index of Weber number. This aspect has been discussed in detail elsewhere.

7.1.3 Comparison between experimental values (based on data banks) and predicted values of a_w.

The values of (a_w/a_t) obtained from the data bank and the values of (a_w/a_t) predicted by using the correlation [Equation (7.3)] are tabulated in Table (7.1.3) and are plotted in Figure (7.1).

The detailed statistical analysis of the corelation [Equation (7.3)] can be described as follows :

(i) The total number of data points used in the correlation is 100 with 21 different systems/variations included.

(ii) The values of % E_{avg}, % E_{abs} and % S_{dev} were -0.45, 7.04, and 3.29 respectively.

(iii) From the 100 data points, 92 % of the predicted values of a_w were within ± 15 % of the experimental data values, 73 % were within ± 10% and 40% were within ± 5 %.

Figure (7.1) shows a parity plot of equation (7.3) wherein the values of $(a_w/a_t)_{pred.}$ have been plotted versus the values of $(a_w/a_t)_{exp.(Lit)}$. The satisfactory correlation fit in Figure (7.1) clearly reflects that equation (7.3) can correlate all the data obtained from various sources covering a wide range of variables as mentioned earlier.

Most of the existing correlation for a_w already surveyed in

Table - (7.1.3)

Comparison between experimental values based on data bank and predicted values of a_w.

No.	a_w m^2/m^3	a_w/a_t exp	a_w/a_t This work	% err	a_w/a_t Onda et al.	% err.
1	79.1	0.460	0.469	-1.96	0.512	-11.32
2	80.8	0.470	0.571	-21.54	0.597	-26.93
3	110.4	0.642	0.592	7.82	0.612	4.67
4	103.2	0.279	0.241	13.61	0.250	10.24
5	135.8	0.367	0.328	10.70	0.340	7.29
6	166.9	0.451	0.414	8.33	0.422	6.37
7	36.8	0.320	0.292	8.73	0.352	-10.02
8	46.0	0.400	0.397	0.71	0.465	-16.32
9	57.5	0.500	0.501	-0.22	0.562	-12.45
10	64.4	0.560	0.632	-12.91	0.664	-18.54
11	107.2	0.228	0.261	-14.44	0.271	-18.65
12	165.0	0.351	0.329	6.21	0.340	3.00
13	164.6	0.445	0.424	4.68	0.465	-4.48
14	188.3	0.509	0.472	7.20	0.509	0.00
15	253.4	0.685	0.582	15.07	0.598	12.69
16	266.4	0.720	0.619	13.97	0.626	13.12
17	88.8	0.240	0.276	-15.14	0.312	-30.04
18	146.5	0.396	0.440	-11.09	0.479	-20.88
19	168.4	0.455	0.504	-10.77	0.535	-17.62
20	185.0	0.500	0.555	-11.01	0.577	-15.33
21	55.5	0.279	0.256	8.20	0.313	-12.31
22	68.1	0.342	0.343	-0.16	0.412	-20.60
23	87.8	0.441	0.425	3.53	0.498	-12.85
24	119.8	0.602	0.627	-4.08	0.665	-10.41
25	69.3	0.210	0.217	-3.49	0.288	-37.13
26	92.4	0.280	0.274	2.07	0.361	-29.00
27	115.5	0.350	0.344	1.74	0.444	-26.88
28	135.3	0.410	0.435	-6.15	0.540	-31.82
29	148.5	0.450	0.468	-4.04	0.572	-27.08
30	198.0	0.600	0.592	1.31	0.675	-12.42
31	35.5	0.187	0.202	-8.07	0.254	-35.78
32	41.2	0.217	0.254	-17.08	0.319	-47.20
33	55.1	0.290	0.322	-10.87	0.399	-37.68
34	71.3	0.375	0.437	-16.66	0.521	-38.89
35	93.1	0.490	0.550	-12.24	0.620	-26.45
36	34.2	0.180	0.169	6.36	0.214	-18.63
37	38.0	0.200	0.212	-6.08	0.271	-35.48
38	47.5	0.250	0.267	-6.68	0.340	-35.92
39	57.0	0.300	0.338	-12.51	0.423	-40.99
40	66.5	0.350	0.363	-3.75	0.451	-28.89
41	79.8	0.420	0.459	-9.35	0.548	-30.45
42	38.0	0.200	0.188	5.86	0.248	-24.23
43	47.5	0.250	0.237	5.21	0.313	-25.30
44	58.9	0.310	0.298	3.90	0.390	-25.69
45	72.2	0.380	0.377	0.78	0.480	-26.30
46	76.0	0.400	0.406	-1.40	0.510	-27.50
47	98.8	0.520	0.513	1.35	0.611	-17.48
48	43.7	0.230	0.222	3.30	0.310	-34.67

Table - 7.1.3 (contd.)

No.	a_w m^2/m^3	a_w/a_t exp	a_w/a_t This work	% err This work	a_w/a_t Onda et al.	% err. Onda et al.
49	57.0	0.300	0.280	6.69	0.386	-28.66
50	72.2	0.380	0.352	7.39	0.473	-24.51
51	91.2	0.480	0.445	7.21	0.572	-19.16
52	98.8	0.520	0.479	7.86	0.604	-16.11
53	117.8	0.620	0.606	2.26	0.706	-13.92
54	28.5	0.150	0.163	-8.58	0.195	-29.97
55	34.2	0.180	0.205	-14.16	0.249	-38.25
56	50.9	0.268	0.258	3.84	0.313	-16.65
57	57.0	0.300	0.353	-17.52	0.420	-40.00
58	76.0	0.400	0.444	-10.94	0.512	-27.91
59	85.1	0.448	0.508	-13.30	0.569	-26.97
60	30.4	0.160	0.155	3.00	0.171	-6.76
61	35.2	0.185	0.196	-5.85	0.219	-18.37
62	52.3	0.275	0.247	10.16	0.278	-1.20
63	58.9	0.310	0.336	-8.37	0.375	-21.07
64	65.6	0.345	0.356	-3.31	0.396	-14.91
65	72.2	0.380	0.385	-1.29	0.425	-11.84
66	77.9	0.410	0.423	-3.14	0.462	-12.58
67	85.5	0.450	0.484	-7.49	0.516	-14.78
68	26.4	0.200	0.174	12.83	0.208	-3.82
69	33.0	0.250	0.220	12.02	0.264	-5.77
70	52.8	0.400	0.377	5.65	0.443	-10.67
71	54.1	0.410	0.475	-15.86	0.537	-30.88
72	114.1	0.195	0.194	0.64	0.197	-1.08
73	155.0	0.265	0.247	6.66	0.255	3.95
74	175.5	0.300	0.280	6.64	0.289	3.77
75	189.5	0.324	0.308	4.80	0.318	1.96
76	200.7	0.343	0.332	3.32	0.341	0.65
77	136.9	0.234	0.243	-4.05	0.271	-16.02
78	181.4	0.310	0.311	-0.27	0.345	-11.45
79	204.8	0.350	0.352	-0.55	0.388	-10.95
80	265.0	0.453	0.417	8.01	0.452	0.25
81	169.6	0.290	0.248	14.59	0.261	9.99
82	201.8	0.345	0.316	8.34	0.333	3.51
83	231.1	0.395	0.358	9.36	0.375	5.15
84	250.4	0.428	0.394	7.87	0.409	4.34
85	264.4	0.452	0.424	6.21	0.437	3.35
86	105.3	0.180	0.179	0.77	0.165	8.22
87	140.4	0.240	0.228	4.99	0.215	10.56
88	162.6	0.278	0.258	7.13	0.244	12.09
89	187.2	0.320	0.284	11.14	0.270	15.70
90	186.0	0.318	0.306	3.87	0.290	8.74
91	96.5	0.165	0.176	-6.72	0.143	13.04
92	114.1	0.195	0.225	-15.28	0.187	4.01
93	143.3	0.245	0.255	-3.89	0.214	12.80
94	158.0	0.270	0.280	-3.82	0.236	12.46
95	166.7	0.285	0.301	-5.75	0.255	10.63
96	99.5	0.170	0.175	-3.06	0.156	7.96
97	134.6	0.230	0.224	2.75	0.204	11.47
98	152.1	0.260	0.253	2.60	0.232	10.75
99	163.8	0.280	0.279	0.39	0.256	8.43
100	175.5	0.300	0.300	0.00	0.276	8.00

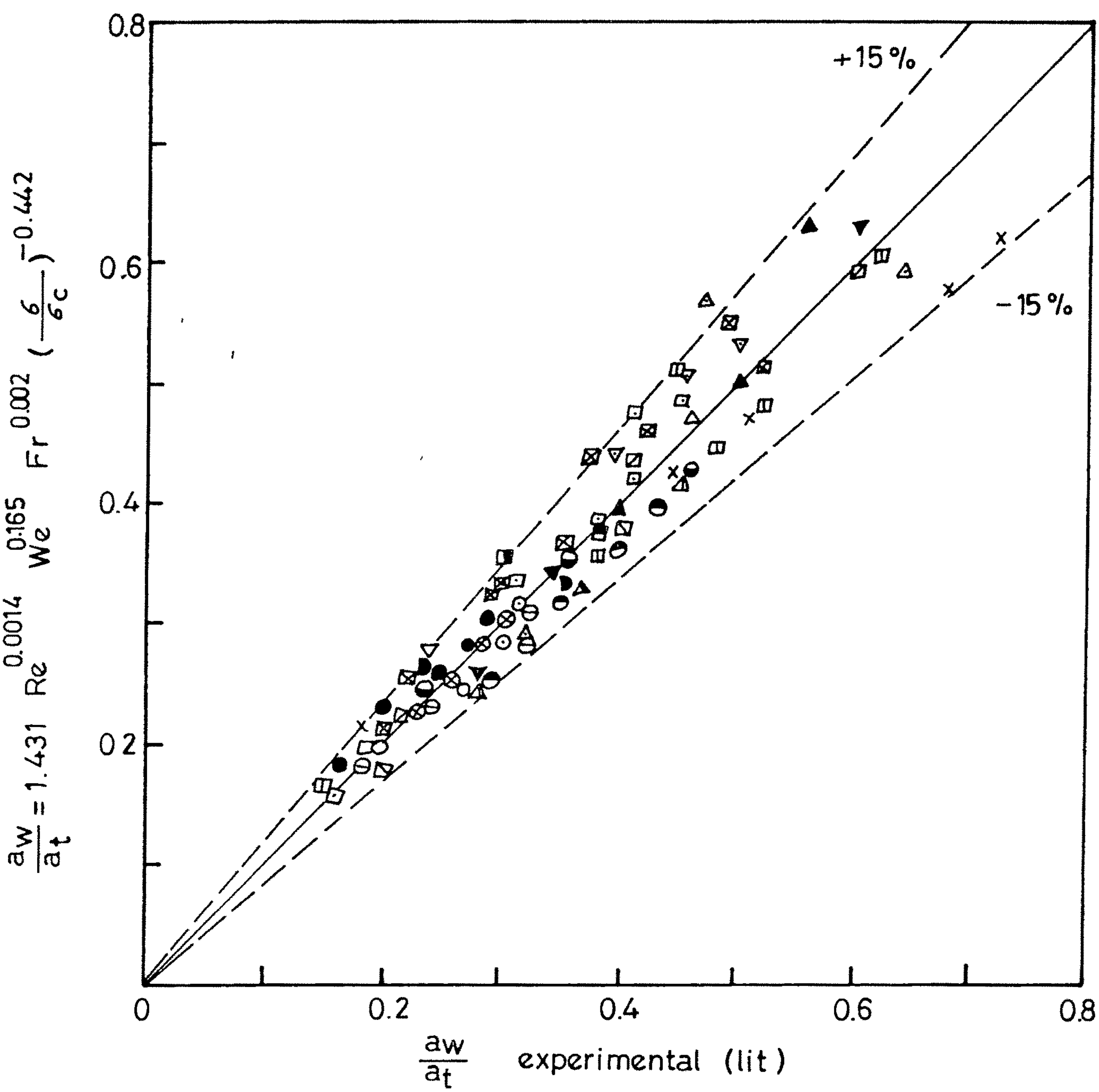

Fig.71 WETTED SURFACE AREA.

COMPARISON OF PREDICTED vs. EXPERIMENTAL (LIT.) DATA.

LEGENDS FOR FIG. 7.1

Data No.	Relevant Information	Symbol
1-10	Shulman (6,7) Air-Water, Napthalene R.R.,	
	dp = 25mm, 13mm, 38mm.	△ ◭ ▲
11-12	Grimley (8),only water flow, C.R.R., 9.5mm.	◗
13-16	Mayo (9), only water flow, Paper R.R., 13 mm.	X
17-24	Fujita (10), only water flow, Paper R.R.,	
	dp= 13mm, 25mm.	▽ ▼
25-30	Hikita (11), water + organic, Paper R.R.,	
	dp = 15mm, σ = 34 mN/m.	⧄
31-67	Hikita (11), water + org. solvents, Paper R.R.,	
	dp = 25mm, σ = 60 to 65 mN/m, 50 mN/m, 38 mN/m.	⊠ ⬒ ⊟
	σ = 62 mN/m, μ_L = 1.62 mNs/m².	◫
	σ = 66 mN/m, μ_L = 3.8 mNs/m².	□
68-71	Hikita (11), water + org. solvents, Paper RR,	
	dp = 35mm, μ_L = 3.8 mNs/m².	⧅
72-100	Onda (12), water + org. solvents, C.R.R., 8mm,	
	σ = 67mN/m, 45 mN/m.	○ ◒
	σ = 45mN/m, μ_L = 2.03mNs/m².	◓
	σ = 75 mN/m.	⊖
	μ_L = 10.8mNs/m², 3.7 mNs/m²	● ⊗

Chapter - (2), are in terms of dimensional quantities. Further these correlations can be utilised to correlate the experimental data of that particular investigator only. The correlation proposed by Onda et al. (97) [Equation (2.5)] in terms of dimensionless numbers perhaps happens to be the correlation which is generalised in nature and which can predict the value of a_w satisfactorily.

The values of (a_w/a_t) obtained by using the generalised correlation proposed by Onda et al. are also reported in Table (7.1.3). The detailed statistical analysis of the correlation of Onda et al. can be described as follows :

(i) The values of % E_{avg}, %E_{abs} and % S_{de_v} were -12.05, 17.04 and 4.29 respectively.

(ii) From the 100 data points only 54 % of the predicted values of a_w were within ± 15 % of the experimental data values, 26 % were within ± 10 % and 16 % were within ± 5 %.

The comparison of the detailed statistical analysis for both these correlations under consideration reveals that the values of E_{abs} for the correlation of Onda and for the correlation developed in this investigation are 17 % and 7 % respectively. Hence, it can be concluded that the generalised correlation developed in this investigation is expected to be superior in comparison to the existing generalised correlation of Onda and coworkers.

7.2.0 RESULTS AND DISCCUSION FOR EFFECTIVE INTERFACIAL AREA DURING PHYSICAL ABSORPTION (a_p) :

7.2.1 Critical analysis of data and mathematical modelling :

A data bank consisting of 100 data points covering 20 variations including systems ammonia-water, CO_2-water, CO_2-methanol, methanol vapour - water etc, reported in Table (5.2) could be used conveniently for analysing the effect of different variables/parameters - L, a_t, ρ_L, μ_L σ and σ_c on the values of a_p.

It is observed that the values of a_p increase with an increase in 'L' and a_t. Changes in packed height do not affect the values of a_p as could be seen from the data fo Yoshida and Koyanagi (14,16). The values of a_p also increase with a decrease in ρ_L,σ and (σ/ σ_c) as observed from the data of Yoshida et al. (14) and Hikita et al. (15). With an increase in μ_L, the values of a_p do decrease, however the effect appears to be quite small as could be seen from the data of Hikita et al. (15).

On the whole, it is observed that the parameters affecting the values of a_p and that affecting the values of a_w are identical. Further the effect of the parameters on the values of a_p and that of a_w also appears to be similar in nature but different in magnitude. Hence with the help of dimensional analysis, an equation similar to that proposed for (a_w/a_t) can also be proposed for the present case. However, it is expected that the values of the indices of the various dimensionless numbers/quantities will be significantly different than that obtained for the correlation of (a_w/a_t). Hence the various dimensionless groups [calculated using the data of a_p reported in Table (5.2)] required for processing of the data for a_p are tabulated in Table (7.2.1).

7.2.2 Statistical analysis for different correlations :

Processing of data reported in Table (7.2.1) was also done by three methodologies namely (i) Multiple linear regression, (ii) Optimization by the DSC-Powell algorithm and (iii) Optimization by the modified simplex algorithm of Nelder and Mead.

The results obtained by use of three methodologies are reported in Table (7.2.2) and are discussed herewith.

CASE I : Using the algorithms of Gauss Jordan and Gauss Seidel yielded the following equations (7.5) and (7.6) respectively :-

$$(a_p/a_t) = 1.832\ (Re)^{-0.031}\ (We)^{0.501}\ (Fr)^{-0.226}\ (\sigma / \sigma_c)^{-0.195} \quad (7.5)$$

$$(a_p/a_t) = 0.2979\ (Re)^{0.31}\ (We)^{0.14}\ (Fr)^{-0.0226}\ (\sigma / \sigma_c)^{-0.339} \quad (7.6)$$

The normal equations obtained by multiple linear regression may not be diagonally dominant. Hence the Gauss Seidel method initially perhaps did not converge for convergence criterias lower than 0.01 as could be seen from regression steps (2) and (3). Further the magnitude of different indices of dimensionless number obtained by Gauss Jordan and Gauss Seidel algorithms differ considerably as could be seen from the comparison of equations (7.5) and (7.6). The effect of different parameters like L, a_t, ρ_L, μ_L, σ and σ_c on the

Table – (7.2.1)

Results inclusive of processing parameters for effective interfacial area during physical absorption (a_p)

No.	a_p m^2/m^3	Re	We $\times 10^5$	Fr $\times 10^5$	σ/σ_c	a_p/a_t exp	a_p/a_t pred	% err
1	26.1	3.42	3.200	0.905	1.193	0.134	0.113	15.57
2	47.6	10.27	28.804	8.145	1.193	0.244	0.205	15.81
3	59.7	17.12	80.010	22.626	1.193	0.306	0.271	11.43
4	71.9	30.82	259.232	73.307	1.193	0.369	0.373	-1.10
5	86.8	51.37	720.088	203.631	1.193	0.445	0.492	-10.63
6	21.4	4.98	4.657	0.622	1.193	0.159	0.127	20.03
7	43.8	14.95	41.916	5.597	1.193	0.326	0.231	29.13
8	57.8	24.92	116.432	15.548	1.193	0.431	0.305	29.21
9	65.6	44.86	377.240	50.375	1.193	0.490	0.420	14.18
10	75.3	74.76	1047.889	139.931	1.193	0.562	0.554	1.33
11	40.0	19.64	55.066	4.261	1.193	0.392	0.252	35.71
12	64.3	58.93	495.590	38.345	1.193	0.630	0.458	27.33
13	52.8	9.77	27.398	8.563	1.193	0.257	0.202	21.45
14	73.3	29.32	246.586	77.067	1.193	0.358	0.367	-2.69
15	40.8	13.91	39.005	6.015	1.193	0.284	0.226	20.28
16	62.4	41.74	351.043	54.135	1.193	0.434	0.411	5.29
17	11.6	1.04	0.295	0.083	1.193	0.060	0.058	3.32
18	14.5	1.59	0.686	0.194	1.193	0.074	0.073	2.29
19	21.0	2.24	1.368	0.387	1.193	0.108	0.088	18.41
20	19.4	3.16	2.729	0.772	1.193	0.099	0.106	-6.64
21	30.8	7.08	13.679	3.868	1.193	0.158	0.165	-4.36
22	36.5	12.88	45.291	12.808	1.193	0.187	0.229	-22.30
23	52.2	23.99	157.052	44.412	1.193	0.268	0.321	-20.10
24	72.0	40.43	446.031	126.131	1.193	0.369	0.428	-15.76
25	19.7	1.82	0.904	0.256	1.193	0.101	0.078	22.56
26	33.5	6.31	10.865	3.073	1.193	0.172	0.155	9.95
27	45.4	10.39	29.469	8.333	1.193	0.233	0.203	12.71
28	57.2	15.85	68.553	19.386	1.193	0.293	0.256	12.70
29	70.9	31.87	277.133	78.369	1.193	0.364	0.375	-3.21
30	22.3	1.67	1.352	1.218	1.193	0.064	0.085	-32.83
31	32.5	2.07	2.079	1.872	1.193	0.093	0.096	-2.59
32	30.1	2.64	3.397	3.059	1.193	0.087	0.110	-26.68
33	13.9	0.58	0.163	0.146	1.193	0.040	0.048	-19.45
34	27.7	1.51	1.108	0.998	1.193	0.080	0.081	-1.45
35	32.3	2.41	2.826	2.545	1.193	0.093	0.104	-12.42
36	43.9	5.82	16.508	14.868	1.193	0.126	0.169	-33.97
37	21.3	1.83	1.601	0.180	0.377	0.109	0.148	-35.34
38	33.5	3.80	6.883	0.772	0.377	0.172	0.221	-28.38
39	41.8	5.58	14.829	1.663	0.377	0.214	0.272	-27.10
40	21.8	0.74	0.324	0.265	1.205	0.066	0.057	14.08
41	29.6	1.46	1.248	1.021	1.205	0.090	0.082	8.41
42	43.7	2.20	2.843	2.324	1.205	0.132	0.103	22.16
43	46.8	2.97	5.177	4.232	1.205	0.142	0.121	14.41
44	54.6	4.42	11.510	9.410	1.205	0.165	0.151	8.72
45	58.7	5.88	20.339	16.629	1.205	0.178	0.176	0.70
46	64.0	7.36	31.895	26.076	1.205	0.194	0.200	-2.98
47	87.4	14.57	124.841	102.066	1.205	0.265	0.290	-9.50
48	70.4	9.37	32.425	10.431	1.205	0.340	0.205	39.77

Table - 7.2.1 (contd.)

No.	a_p m^2/m^3	Re	We $\times 10^5$	Fr $\times 10^5$	σ/σ_c	a_p/a_t exp	a_p/a_t pred	% err
49	76.6	11.74	50.847	16.357	1.205	0.370	0.232	37.40
50	104.5	23.23	199.022	64.023	1.205	0.505	0.336	33.39
51	54.6	1.62	1.377	0.425	0.359	0.165	0.145	12.44
52	65.5	3.19	5.314	1.642	0.359	0.199	0.210	-5.56
53	71.8	4.81	12.101	3.739	0.359	0.217	0.262	-20.71
54	93.6	6.49	22.035	6.808	0.359	0.284	0.309	-9.03
55	109.2	9.68	48.991	15.136	0.359	0.331	0.385	-16.28
56	124.8	12.86	86.574	26.747	0.359	0.378	0.450	-18.89
57	131.0	16.11	135.760	41.943	0.359	0.397	0.508	-28.05
58	188.8	31.87	531.382	164.169	0.359	0.572	0.739	-29.11
59	64.2	5.08	8.471	1.030	0.359	0.310	0.243	21.55
60	82.8	7.67	19.292	2.345	0.359	0.400	0.305	23.85
61	89.0	10.35	35.129	4.270	0.359	0.430	0.359	16.55
62	105.6	15.43	78.101	9.494	0.359	0.510	0.447	12.48
63	124.2	20.51	138.016	16.778	0.359	0.600	0.522	13.04
64	140.8	25.68	216.428	26.309	0.359	0.680	0.590	13.23
65	109.2	5.90	87.321	32.561	0.492	0.331	0.363	-9.71
66	120.1	9.41	139.207	20.425	0.492	0.580	0.421	27.37
67	90.5	5.27	61.436	28.654	0.656	0.274	0.292	-6.60
68	104.5	8.39	97.941	17.974	0.656	0.505	0.339	32.82
69	78.0	7.11	43.405	27.042	0.902	0.236	0.242	-2.43
70	86.9	11.33	69.197	16.963	0.902	0.420	0.281	33.11
71	49.9	1.20	7.604	5.377	1.148	0.151	0.124	18.29
72	65.5	2.41	30.415	21.508	1.148	0.199	0.181	9.05
73	90.5	4.81	121.659	86.030	1.148	0.274	0.264	3.77
74	74.9	3.64	69.421	49.091	1.148	0.227	0.226	0.26
75	49.9	1.13	7.553	5.006	1.115	0.151	0.124	17.89
76	65.5	2.26	30.211	20.025	1.115	0.199	0.181	8.60
77	74.9	3.41	68.956	45.706	1.115	0.227	0.227	0.00
78	90.5	4.52	120.843	80.099	1.115	0.274	0.265	3.30
79	21.9	0.65	0.287	0.262	1.208	0.063	0.055	13.14
80	20.6	0.67	0.307	0.280	1.210	0.059	0.056	6.14
81	28.2	1.62	1.752	1.597	1.208	0.081	0.090	-10.74
82	31.1	1.63	1.808	1.649	1.209	0.089	0.090	-1.10
83	34.9	2.90	5.970	5.455	1.211	0.100	0.125	-24.30
84	40.5	3.38	7.361	6.703	1.207	0.116	0.133	-14.29
85	20.3	0.65	0.284	0.259	1.208	0.058	0.054	6.51
86	21.1	0.66	0.290	0.264	1.208	0.061	0.055	9.54
87	19.6	0.75	0.331	0.300	1.202	0.056	0.057	-1.68
88	27.9	1.80	1.822	1.649	1.200	0.080	0.092	-14.27
89	28.3	1.70	1.912	1.742	1.208	0.081	0.092	-12.80
90	45.4	3.50	7.637	6.943	1.205	0.131	0.135	-3.13
91	23.9	3.02	3.160	0.902	1.205	0.122	0.109	11.27
92	23.1	2.93	3.229	0.924	1.208	0.118	0.109	8.20
93	27.2	3.17	3.504	0.999	1.203	0.140	0.112	19.91
94	43.7	5.37	12.232	3.521	1.215	0.224	0.155	30.80
95	75.9	16.78	114.196	32.771	1.211	0.389	0.287	26.31
96	27.2	3.24	3.278	0.931	1.199	0.139	0.111	20.62
97	26.1	3.08	3.441	0.984	1.207	0.134	0.111	17.26
98	24.6	3.18	3.858	1.105	1.209	0.126	0.114	9.59
99	41.6	6.85	15.668	4.460	1.202	0.213	0.169	20.78
100	84.6	18.89	129.663	37.068	1.207	0.434	0.299	31.05

Table – (7.2.2)

Statistical analysis for different correlations of a_p

Correlation Structure : $a_p / a_t = C \cdot Re^{\alpha} \cdot We^{\beta} \cdot Fr^{\gamma} \cdot (\sigma / \sigma_c)^{\delta}$.

No.	C	α	β	γ	δ	% E_{avg}	% E_{abs}	% S_{dev}
Case 1 :– Multiple Linear Regression								
Numerical Method : Gauss Jordan algorithm.								
1	1.832	–0.0312	0.5013	–0.226	–0.195	–1.26	12.5	4.57
Numerical Method : Gauss Seidel algorithm.								
2	Convergence criteria ε = 0.001				Overflow			
3	Convergence criteria ε = 0.005				Overflow			
4	Convergence criteria ε = 0.01							
	0.2979	0.3129	0.14	–0.0226	–0.339	2.268	16.01	5.76
Case 2 :– Optimisation by the D S C – Powell algorithm.								
Initialisation were based on arbitary guesses of indices, α β, γ, δ, and C were fed as 0.02, 0.8, 0.0.02, 0.05, 3.0.								
Direction of search sequence α, β, δ, γ, C. respectively.								
5	0.9442	0.1037	0.188	0.024	–0.482	9.04	17.47	6.42.
Direction of search sequence as in step 5, initialisation based on values of indices of step no. 5. However α, γ values fed as 0.001.								
6	1.005	0.0906	0.2168	0.002	–0.46	8.68	16.84	6.18.
Direction of search sequence changed to C, β, δ, α, γ. Initialisation as in step no 6.								
7	1.056	0.1017	0.22	0.002	–0.448	5.1	16.07	6.00.
Direction of search sequence changed to δ, C, β, α, γ. Initialisation as in step no. 6.								
8	1.031	0.108	0.219	0.002	–0.439	5.65	16.04	5.95.

Table – 7.2.2 (contd.)

No.	C	α	β	γ	δ	% E_{avg}	% E_{abs}	% S_{dev}

Direction of search sequence as in step no. 8, initialisation done by values of step no. 7.

9	1.054	0.1043	0.221	0.002	-0.442	5.89	16.08	5.97.

Direction of search sequence changed to β, C, δ, α, γ. Initialisation as in step no. 6.

10*	1.08	0.0992	0.222	0.002	-0.442	3.45	15.66	5.97.

Case 3 : – Optimisation by the Modified Simplex algorithm of Nelder and Mead

All parameters are iterated, base values as obtained from step no 10. Each indice value perturbed 50 % at a time.

11	1.092	0.102	0.226	0.00239	-0.445	2.4	16.41	5.99.

γ value fixed as 0.0024. Other parameters iterated as in step 11.

12	1.1034	0.1014	0.226	0.0024	-0.431	6.58	16.12	5.94.

δ value fixed as 0.589 (as obtained in wetted area). Other parameters iterated as in step 11.

13	1.299	0.079	0.237	0.0024	-0.589	2.3	17.76	7.18.

γ fixed as 0.002 as obtained in steps 6 to 10.

14	1.158	0.096	0.23	0.002	-0.441	5.76	16.14	5.98.

C fixed as 1.431 as obtained in wetted areas. Other parameters iterated as in step 11.

15	1.431	0.053	0.238	0.0626	-0.295	4.0	15.55	6.06.

C fixed as 1.431, δ fixed as -0.442. Other parameters iterated as in step no. 11.

16	1.431	0.0528	0.241	0.002	-0.442	1.59	16.27	6.09.

C fixed as 1.431 and γ fixed as 0.002. Other parameters iterated as in step no. 11.

17	1.431	0.0497	0.2434	0.002	-0.2691	5.22	15.38	6.15.

Table - 7.2.2 (contd.)

No.	C	α	β	γ	δ	% E_{avg}	% E_{abs}	% S_{dev}
C, γ, δ fixed as 1.431, 0.002,-0.442 respectively. Other parameters iterated as in step no 11.								
18	1.431	0.027	0.2427	0.002	-0.442	7.01	16.58	6.35.
C, α, γ, δ fixed as 1.431, 0.0014, 0.002, -0.442 respectively. Only β iterated as in step no. 11.								
19	1.431	0.0014	0.237	0.002	-0.442	5.99	17.38	6.73.
C, β, γ, δ fixed as 1.431, 0.165, 0.002, -0.442 respectively. Only α is iterated as in step no 11.								
20	1.431	-0.282	0.165	0.002	-0.442	28.7	60.2	13.8.

Note : The values of indices in the finalised generalised correlation are as per regression step marked by (*)

value of a_p reflected in these two equations appears to be contradictory. For example equation (7.5) indicates that with an increase in μ_L the value of (a_p/a_t) is expected to increase (Re index being negative), while equation (7.6) indicates that with an increase in μ_L the value of (a_p/a_t) is expected to decrease considerably (Re index being positive and of high magnitude). Similarly, other contradictory observations can be made from the indices of other dimensionless numbers like We, Fr and (σ / σ_c). Further, the correlation (7.6) obtained by Gauss Seidel methodology appears to be to some extent inferior in comparison to the correlations (7.5) obtained by Gauss Jordan methodology as could be seen from the values E_{abs} being 16.01 % and 12.5 % respectively.

Thus it could be observed that by using different numerical methods sometimes misleading results can be obtained/inconsistent results are also likely to be obtained. Also correlations having inferior statistical analysis are likely to be developed. Hence while using different optimization techniques one must be very careful in order to obtain a generalized correlation by mathematical modelling.

CASE II : It was observed that using methodology ; optimization by the DSC-Powell algorithm by changing the direction of search sequences, some decrease in the values of % E_{abs} was obtained. The values of % E_{abs} for regression steps (5) and (10) were 17.47 and 15.66 respectively.

By performing regression as per step (10), yielded the following equation :-

$$(a_p/a_t) = 1.08\ (Re)^{0.099}\ (We)^{0.222}\ (Fr)^{0.002}\ (\sigma\ /\ \sigma_c)^{-0.442} \qquad (7.7)$$

Though the data fit by this correlation (equation 7.7) is expected to be to some extent inferior than the correlation (7.5), the interpretation of the experimental data on a_p and their parametric dependencies involves no problems. The values of different indices obtained in equation (7.7) and the effect of different parameters on the values of a_p thus involves no ambiguity.

CASE III : It was observed that using the modified simplex algorithm of Nelder and Mead and performing regressions as per steps (11) to (20) by prefixing indices of some number did not alter the statistical analysis appreciably, exception being the regression step (20). The values of % E_{avg}, % E_{abs} and % S_{dev} remained in the ranges of (2 to 7), (15.5 to 17.5) and (6 to 7) respectively.

In regression step (19), all the indices except that of Weber number (We) were prefixed to C = 1.431, α = 0.0014, γ = 0.002 and δ = -0.442. These indices were obtained from a generalised correlation which had been already developed for predicting the values (a_w/a_t) by equation (7.3). The regression of the data was performed to optimise for power of Weber number (We). This methodology resulted in the following correlation having the statistical analysis as % E_{avg} = 5.99, % E_{abs} = 17.38 and % S_{dev} = 6.731 :-

$$(a_p/a_t) = 1.431\ (Re)^{0.0014}\ (We)^{0.237}\ (Fr)^{0.002}\ (\sigma\ /\ \sigma_c)^{-0.442} \qquad (7.8)$$

In regression step (20) all the indices except that of Reynolds number (Re) were prefixed to C = 1.431, β = 0.165, γ = 0.002 and δ = -0.442. [These indices were obtained from a generalised correlation which was developed for predicting the values of (a_w/a_t) by equation (7.3)]. The regression of the data was performed to optimise the power of Re. This methodology resulted in the following correlation having the statistical analysis of % E_{avg} = 28.7, % E_{abs} = 60.22 and % S_{dev} = 13.8.

$$(a_p/a_t) = 1.431\ (Re)^{-0.282}\ (We)^{0.165}\ (Fr)^{0.002}\ (\sigma / \sigma_c)^{-0.442} \qquad (7.9)$$

Thus, under these conditions the algorithm failed to minimize the error by altering the index appropriately. Hence Weber number appears to be the most dominating parameter affecting the values of a_p in comparison to all other parameters.

The data fit of a_p by equation (7.8) is expected to be to some extent inferior than the data fit of a_p by equation (7.7). However, this equation could also be considered as a satisfactory correlation for predicting the values of (a_p). It is interesting to observe that all the indices of different groups in equation (7.8) which correlates data on a_p and that in equation (7.3) which correlates data on a_w, are identical except the index of Weber number.

7.2.3 Comparison between experimental values (based on data banks) and predicted values of a_p :

The values of (a_p/a_t) obtained from the data bank of a_p and the values of (a_p/a_t) predicted by using equation (7.7) are tabulated in Table (7.2.3) and are plotted in Figure (7.2). The detailed statistical analysis of the correlation [Equation (7.7)] can be described as follows :

(i) The total number of data points used in the correlation is 100 with 20 different systems/variations included.

(ii) The values of % E_{avg}, % E_{abs}, and % S_{dev} were 3.45, 15.66 and 5.97 respectively.

(iii) Out of 100 data points 77% of the predicted values of a_p were within ± 25 % of the experimental data values, 63 % were within ± 20% and 51% were within ± 15 % error.

(iv) From 100 data points only 13 points had deviations above ± 30%, and the value of maximum deviation observed was + 39.77 %.

Figure (7.2) shows a parity plot of equation (7.7) where in the values of $(a_p/a_t)_{pred}$ have been plotted versus $(a_p/a_t)_{exp.(Lit)}$. The satisfactory fit obtained for majority of data points indicate that the correlation can satisfactorily correlate the data of a_p obtained from various sources covering a wide range of variables mentioned earlier.

The existing correlations for predicting the values of a_p surveyed in Chapter - (2) : Literature Survey were mostly developed by their respective investigators using limited data bank. However the correlation proposed by Zech and Mersmann (104) [Equation - (2.8)] based on theoretical considerations, was developed using a

Table - (7.2.3)

Comparison between experimental values based on data bank and predicted values of a_p

No.	a_p m^2/m^3	a_p/a_t exp	a_p/a_t This work	% err This work	a_p/a_t Mersmann et al.	% err Mersmann et al.	a_p/a_t Billet et al.	% err Billet et al.
1	26.1	0.134	0.113	15.57	0.095	28.78	0.160	-19.15
2	47.6	0.244	0.205	15.81	0.165	32.26	0.248	-1.55
3	59.7	0.306	0.271	11.43	0.213	30.29	0.304	0.70
4	71.9	0.369	0.373	-1.10	0.286	22.41	0.385	-4.21
5	86.8	0.445	0.492	-10.63	0.370	16.94	0.472	-6.00
6	21.4	0.159	0.127	20.03	0.113	28.83	0.223	-39.79
7	43.8	0.326	0.231	29.13	0.196	39.85	0.346	-5.87
8	57.8	0.431	0.305	29.21	0.254	41.22	0.424	1.70
9	65.6	0.490	0.420	14.18	0.340	30.51	0.536	-9.57
10	75.3	0.562	0.554	1.33	0.439	21.85	0.658	-17.09
11	40.0	0.392	0.252	35.71	0.222	43.51	0.474	-20.71
12	64.3	0.630	0.458	27.33	0.384	39.10	0.735	-16.69
13	52.8	0.257	0.202	21.45	0.157	38.92	0.226	12.23
14	73.3	0.358	0.367	-2.69	0.272	23.84	0.351	1.94
15	40.8	0.284	0.226	20.28	0.183	35.58	0.329	-15.86
16	62.4	0.434	0.411	5.29	0.317	27.00	0.510	-17.62
17	11.6	0.060	0.058	3.32	0.053	11.94	0.099	-66.00
18	14.5	0.074	0.073	2.29	0.065	12.76	0.117	-57.66
19	21.0	0.108	0.088	18.41	0.077	28.32	0.135	-25.14
20	19.4	0.099	0.106	-6.64	0.092	7.82	0.155	-55.45
21	30.8	0.158	0.165	-4.36	0.137	13.15	0.213	-35.14
22	36.5	0.187	0.229	-22.30	0.185	1.04	0.271	-45.03
23	52.2	0.268	0.321	-20.10	0.253	5.62	0.348	-29.98
24	72.0	0.369	0.428	-15.76	0.328	11.24	0.429	-16.03
25	19.7	0.101	0.078	22.56	0.070	31.30	0.124	-22.45
26	33.5	0.172	0.155	9.95	0.130	24.65	0.204	-18.60
27	45.4	0.233	0.203	12.71	0.166	28.65	0.249	-6.83
28	57.2	0.293	0.256	12.70	0.205	30.05	0.295	-0.41
29	70.9	0.364	0.375	-3.21	0.291	19.96	0.390	-7.14
30	22.3	0.064	0.085	-32.83	0.041	36.73	0.081	-26.26
31	32.5	0.093	0.096	-2.59	0.045	51.62	0.088	5.52
32	30.1	0.087	0.110	-26.68	0.051	40.95	0.097	-12.53
33	13.9	0.040	0.048	-19.45	0.024	40.20	0.053	-32.66
34	27.7	0.080	0.081	-1.45	0.039	51.45	0.078	2.15
35	32.3	0.093	0.104	-12.42	0.049	47.37	0.094	-1.22
36	43.9	0.126	0.169	-33.97	0.076	39.83	0.134	-5.95
37	21.3	0.109	0.148	-35.34	0.106	3.28	0.223	-103.70
38	33.5	0.172	0.221	-28.38	0.152	11.35	0.298	-73.58
39	41.8	0.214	0.272	-27.10	0.185	13.80	0.348	-62.43
40	21.8	0.066	0.057	14.08	0.028	58.13	0.065	2.06
41	29.6	0.090	0.082	8.41	0.039	56.76	0.085	5.46
42	43.7	0.132	0.103	22.16	0.048	63.96	0.100	24.37
43	46.8	0.142	0.121	14.41	0.055	60.92	0.113	20.43
44	54.6	0.165	0.151	8.72	0.068	59.10	0.132	19.97
45	58.7	0.178	0.176	0.70	0.078	56.10	0.148	16.52
46	64.0	0.194	0.200	-2.98	0.087	54.95	0.162	16.24
47	87.4	0.265	0.290	-9.50	0.123	53.61	0.213	19.43
48	70.4	0.340	0.205	39.77	0.153	55.12	0.247	27.43
49	76.6	0.370	0.232	37.40	0.171	53.85	0.270	27.03

Table - 7.2.3 (contd.)

No.	a_p m^2/m^3	a_p/a_t exp	a_p/a_t This work	% err	a_p/a_t Mersmann et al.	% err	a_p/a_t Billet et al.	% err
50	104.5	0.505	0.336	33.39	0.240	52.44	0.355	29.76
51	54.6	0.165	0.145	12.44	0.064	61.62	0.133	19.85
52	65.5	0.199	0.210	-5.56	0.089	55.17	0.174	12.50
53	71.8	0.217	0.262	-20.71	0.109	49.72	0.205	5.81
54	93.6	0.284	0.309	-9.03	0.127	55.22	0.231	18.59
55	109.2	0.331	0.385	-16.28	0.155	53.13	0.271	18.13
56	124.8	0.378	0.450	-18.89	0.179	52.72	0.304	19.73
57	131.0	0.397	0.508	-28.05	0.200	49.61	0.332	16.35
58	188.8	0.572	0.739	-29.11	0.281	50.80	0.436	23.71
59	64.2	0.310	0.243	21.55	0.174	43.85	0.289	6.80
60	82.8	0.400	0.305	23.85	0.214	46.55	0.341	14.84
61	89.0	0.430	0.359	16.55	0.248	42.24	0.384	10.70
62	105.6	0.510	0.447	12.48	0.303	40.55	0.451	11.69
63	124.2	0.600	0.522	13.04	0.350	41.72	0.505	15.85
64	140.8	0.680	0.590	13.23	0.391	42.45	0.552	18.76
65	109.2	0.331	0.363	-9.71	0.111	66.36	0.327	1.24
66	120.1	0.580	0.421	27.37	0.218	62.47	0.543	6.30
67	90.5	0.274	0.292	-6.60	0.095	65.33	0.272	0.77
68	104.5	0.505	0.339	32.82	0.186	63.18	0.452	10.37
69	78.0	0.236	0.242	-2.43	0.097	58.98	0.203	14.26
70	86.9	0.420	0.281	33.11	0.190	54.86	0.337	19.76
71	49.9	0.151	0.124	18.29	0.038	75.09	0.162	-7.04
72	65.5	0.199	0.181	9.05	0.053	73.16	0.214	-7.61
73	90.5	0.274	0.264	3.77	0.075	72.51	0.282	-2.83
74	74.9	0.227	0.226	0.26	0.065	71.13	0.252	-11.06
75	49.9	0.151	0.124	17.89	0.038	75.16	0.169	-11.39
76	65.5	0.199	0.181	8.60	0.053	73.23	0.222	-11.99
77	74.9	0.227	0.227	0.00	0.065	71.21	0.262	-15.57
78	90.5	0.274	0.265	3.30	0.075	72.59	0.293	-7.00
79	21.9	0.063	0.055	13.14	0.025	59.73	0.061	2.95
80	20.6	0.059	0.056	6.14	0.026	56.78	0.062	-4.75
81	28.2	0.081	0.090	-10.74	0.040	50.73	0.088	-8.22
82	31.1	0.089	0.090	-1.10	0.040	55.26	0.088	1.09
83	34.9	0.100	0.125	-24.30	0.053	46.96	0.113	-12.07
84	40.5	0.116	0.133	-14.29	0.058	50.55	0.116	0.00
85	20.3	0.058	0.054	6.51	0.025	56.65	0.061	-4.54
86	21.1	0.061	0.055	9.54	0.025	58.02	0.061	0.00
87	19.6	0.056	0.057	-1.68	0.027	51.67	0.062	-10.10
88	27.9	0.080	0.092	-14.27	0.042	47.47	0.087	-8.61
89	28.3	0.081	0.092	-12.80	0.041	49.88	0.089	-9.48
90	45.4	0.131	0.135	-3.13	0.059	55.10	0.117	10.41
91	23.9	0.122	0.109	11.27	0.089	27.16	0.162	-32.72
92	23.1	0.118	0.109	8.20	0.088	25.82	0.164	-38.67
93	27.2	0.140	0.112	19.91	0.092	34.42	0.166	-18.92
94	43.7	0.224	0.155	30.80	0.119	47.14	0.216	3.45
95	75.9	0.389	0.287	26.31	0.210	46.09	0.337	13.35
96	27.2	0.139	0.111	20.62	0.093	33.48	0.162	-16.54
97	26.1	0.134	0.111	17.26	0.090	32.76	0.166	-23.72
98	24.6	0.126	0.114	9.59	0.091	27.49	0.170	-35.10
99	41.6	0.213	0.169	20.78	0.135	36.87	0.223	-4.72
100	84.6	0.434	0.299	31.05	0.223	48.59	0.343	20.98

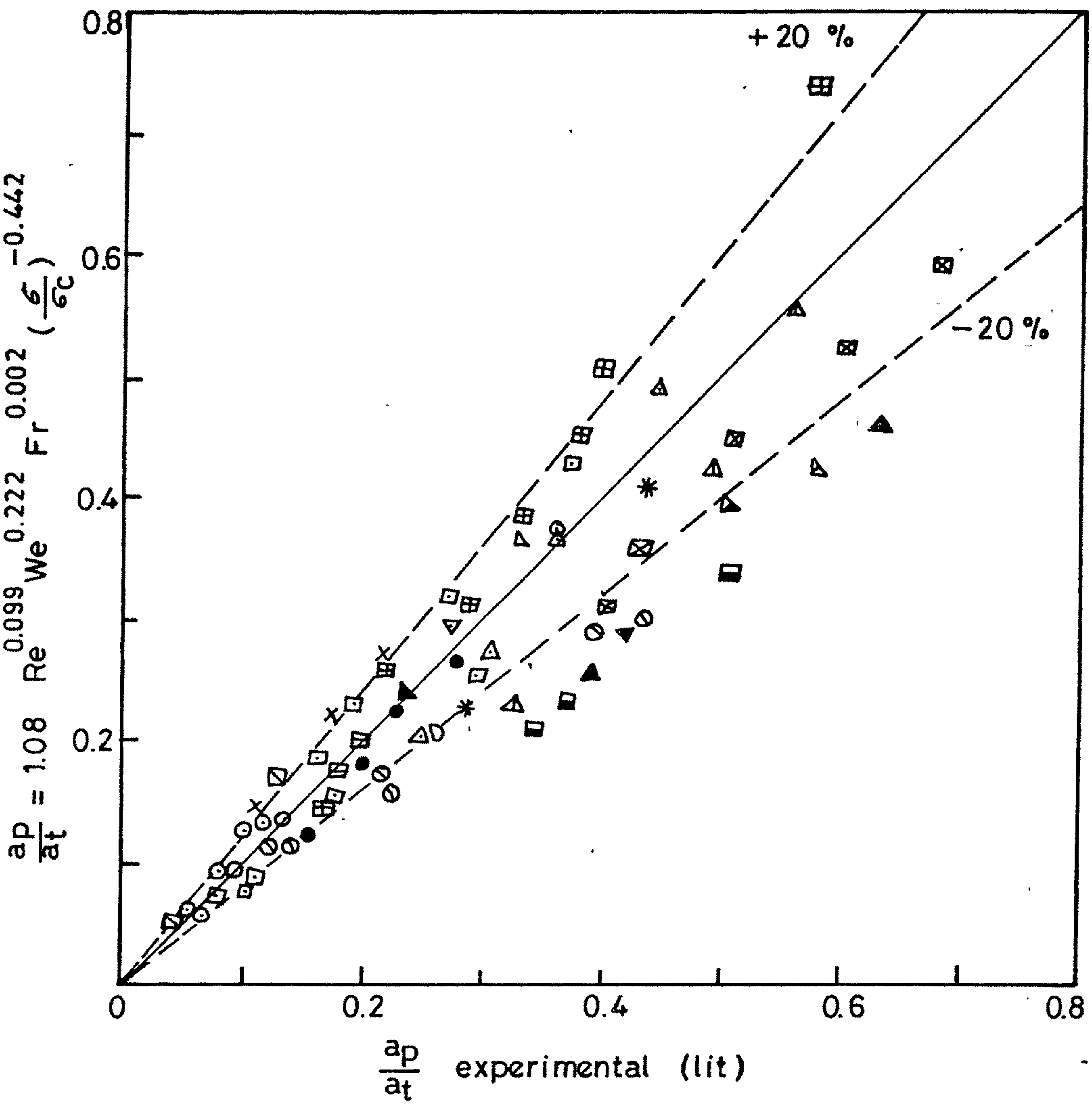

Fig. 7.2 EFFECTIVE INTERFACIAL AREA DURING PHYSICAL ABSORPTION.

COMPARISON OF PREDICTED vs. EXPERIMENTAL (LIT.) DATA.

LEGENDS FOR FIG. 7.2

Data No.	Relevant Details	Symbol
1-12	Fellinger's data (14), NH_3 - Water, C.R.R., 25mm, 38mm, 50mm.	△ ⚠ ▲
13-16	Fellinger's data (14), NH_3 - Water, Ceramic Berl Saddle, 25mm, 38mm.	D ✱
17-36	Yoshida (15), CO_2 - Water, C.R.R., 25mm, 15mm.	□ ⧅
37-39	Yoshida (15), CO_2 - Methanol, C.R.R., 25mm, σ = 23 mN/m.	X
40-50	Hikita (16), CO_2 - Water, C.R.R., 15mm, 25mm.	⊟ ⬓
51-64	Hikita (16), CO_2 - Methanol, C.R.R., 15mm, 25mm.	⊞ ⊠
65-66	Hiki‹a (16), CO_2 - 60 % Methanol, σ = 30mN/m, C.R.R., 15mm, 25mm.	◺ ◺
67-68	Hikita (16), CO_2 - 30 % Methanol, σ = 40 mN/m, C.R.R., 15mm, 25mm.	◸ ◣
69-70	Hikita (16), CO_2 - 10 % Methanol, σ = 55 mN/m, C.R.R., 15mm, 25mm.	◣ ▼
71-78	Hikita (16), CO_2 - 5 to 10 % cane sugar, μ_L = 3.5 mNs/m² ., C.R.R., 15mm.	●
79-100	Yoshida (17), Methanol vapour - water, C.R.R., 25mm, 25 mm.	○ ⦶

wide range of systems/variations. Therefore, the values of (a_p/a_t) obtained by using the correlations of Zech and Mersmann are also reported in Table (7.2.3) for comparison purpose. The detailed statistical analysis of (a_p/a_t) values obtained by this correlation can be described as follows :

(i) The values of % E_{avg}, % E_{abs}, % S_{dev} were 42.9, 42.9, and 7.83 respectively.

(ii) Out of 100 data points only 24 % of the predicted values of a_p were within ± 30 % of the experimental data values.

(iii) From 100 data points, 76 points had deviations above ± 30% and the maximum deviation observed was 75 %.

The recently proposed correlation by Billet and Schultes (105) [Equation (2.9)] also appears to be a generalised correlation. The values of (a_p/a_t) obtained by the correlation of Billet and Schultes are also reported in Table (7.2.3). The detailed statistical analysis of (a_p/a_t) values obtained by the correlation of Billet and Schultes can be described as follows :

(i) The values of % E_{avg}, % E_{abs} and % S_{dev} were - 6.3, 17.4 and 5.25 respectively.

(ii) Out of 100 data points 79 % of predicted values of a_p were within ± 25 % of the experimental data values and 65% were within ± 15 %.

(iii) From 100 data points, 13 points had deviations greater than ± 30 %, and 6 points had deviations greater than ± 50 %. Further the maximum deviation observed was -103.7 %.

The comparison of detailed statistical analysis for the three correlations under consideration reveals that the values of % E_{abs}, for the correlation of Zech & Mersmann, Billet and Schultes and for the correlation developed in this investigation are 42.9, 17.4 and 15.66 respectively. Hence it can be concluded that the generalised correlation developed in this investigation is expected to be superior in comparison to the existing generalised correlations of Zech and Mersmann. The statistical analysis for the correlation of Billet and Schultes and that for the correlation developed in this investigation is comparable, exception being the value of maximum deviation observed in both this correlations. Since the range of maximum deviation values for the correlation developed in this investigation is of the order ± 30 % to ± 40 % and that of Billet's correlation is ± 50 to - 103.7 %, the correlation proposed in this investigation [Equation (7.7)] appears to be better than that proposed by Billet and Schultes.

7.3.0 RESULTS AND DISCUSSION FOR EFFECTIVE INTERFACIAL AREA DURING CHEMICAL ABSORPTION (a_c) :

7.3.1 Critical analysis of data and mathematical modelling :

A data bank consisting of 167 data points covering 32 different variations inclusive of system variations like CO_2-NaOH CO_2-potassium buffer solutions, sulphite oxidation, dithionite oxidation etc. reported in Table - (5.3) could be conveniently used for analysing the effect of different variables on the values of a_c.

The parameters that affect a_c are the liquid flow rate (L) the physical properties of the absorption media like density (ρ_L) viscosity (μ_L), surface tension (σ), surface area of packing (a_t) and the critical surface tension of the packing material (σ_c).

The values of a_c increase with an increase in L and decrease with an increase in ρ_L, μ_L, and σ. The data of Danckwerts et al. (19) and Richards et al. (21) indicate that under otherwise similar conditions with an increase in the viscosity by 30 %,the value of a_c decreases by approximately by 10 %. Similar observations can be made from the data of Rizzuti and coworkers (37). The data of Jhaveri (25,26) indicates only a marginal decrease in the values of a_c with a two fold increase in the value of viscosity. It appears that (σ / σ_c) is the dominant parameter affecting the values of a_c. The data of Sahay (31), Andrieu and Claudel (32), Andrieu (34), and Linek (33) indicate that with a two fold increase in (σ / σ_c) value, the values of a_c decrease appreciably.

On the whole, it is thus observed that the parameters affecting the value of a_c and those affecting the values of a_w and a_p are identical. Further, the effect of these parameters on the values of a_c and that on the values of a_w and a_p also appears to be similar in nature but different in magnitude.

Hence, with the help of dimensional analysis, an equation similar to that for (a_w/a_t) can be proposed. However, it is expected that the indices of the various dimensionless numbers will be significantly different than those obtained for the correlations of (a_w/a_t) and (a_p/a_t). The relevant dimensionless groups [calculated using the data of a_c reported in Table (5.3)] required for processing the data of a_c are tabulated in Table (7.3.1).

7.3.2 Statistical analysis for different correlations :

Processing of the data reported in Table (7.3.1) was also done by three metodologies namely (i) Mulitple linear regression, (ii) Optimization by the DSC - Powell algorithm and (iii) Optimization by the modified simplex algorithm of Nelder and Mead. The results obtained by using these three methodologies are reported in Table (7.3.2) and are discussed herewith.

CASE I : Multiple linear regression using the Gauss Jordan and Gauss Seidel methods gave practically comparable statistics as could be seen from the the regression steps (1) to (3), wherein the values of E_{avg}, E_{abs} and S_{dev} were of the order -0.5 %, 8.8 %, 4.8 % respectively.

CASE II : It was observed that using the methodology of optimization by the DSC - Powell algorithm, by changing the direction of search sequence some decrease in the values % E_{abs} and % E_{avg} was obtained. The values of E_{abs} and E_{avg} for the regression steps (7) and (6) were (10.4 % and - 0.33 %) and (9.7 % and 0.086 %) respectively.

CASE III : Using the modified simplex algorithm of Nelder and Mead by performing regression as per step (9) to (13) which also included

Table - (7.3.1)

Results inclusive of processing parameters for effective interfacial area during chemical absorption (a_c)

No.	a_c m^2/m^3	Re	We $\times 10^5$	Fr $\times 10^5$	σ/σ_c	a_c/a_t exp	a_c/a_t pred	% err
1	106.0	3.09	8.387	7.988	1.230	0.286	0.266	7.02
2	134.0	4.45	6.821	6.806	1.148	0.362	0.308	14.84
3	141.0	8.66	25.860	25.804	1.148	0.381	0.389	-1.98
4	154.0	13.04	58.732	58.603	1.148	0.416	0.448	-7.66
5	82.0	1.92	1.969	1.957	1.213	0.222	0.222	0.00
6	97.0	3.86	7.986	7.938	1.213	0.262	0.284	-8.19
7	120.0	5.75	17.722	17.615	1.213	0.324	0.326	-0.42
8	127.5	7.73	31.944	31.752	1.213	0.345	0.361	-4.69
9	144.5	9.65	49.781	49.481	1.213	0.391	0.390	0.24
10	63.0	29.14	207.594	25.450	1.230	0.485	0.535	-10.46
11	78.0	37.98	352.787	43.250	1.230	0.600	0.587	2.19
12	92.7	60.37	891.107	109.244	1.230	0.713	0.689	3.35
13	110.0	75.96	1411.149	172.998	1.230	0.846	0.746	11.78
14	119.0	87.14	1856.774	227.629	1.230	0.915	0.783	14.48
15	128.0	0.62	15.881	12.123	0.902	0.272	0.270	0.73
16	156.0	1.11	51.020	38.948	0.902	0.332	0.331	0.27
17	172.0	1.61	108.211	82.608	0.902	0.366	0.377	-3.06
18	126.0	2.58	6.204	9.530	1.200	0.268	0.258	3.71
19	142.0	4.02	15.112	23.216	1.200	0.302	0.301	0.29
20	154.0	4.90	22.448	34.486	1.200	0.328	0.323	1.52
21	168.0	6.16	35.465	54.485	1.200	0.357	0.349	2.27
22	179.0	7.35	50.437	77.487	1.200	0.381	0.371	2.50
23	187.0	8.61	69.293	106.455	1.200	0.398	0.392	1.38
24	190.0	9.97	92.936	142.777	1.200	0.404	0.413	-2.13
25	141.0	2.41	5.434	8.348	1.200	0.300	0.252	15.91
26	178.0	4.81	21.599	33.182	1.200	0.379	0.321	15.37
27	206.0	7.28	49.461	75.986	1.200	0.438	0.370	15.57
28	143.0	2.54	6.033	9.268	1.200	0.304	0.257	15.57
29	181.0	5.00	23.393	35.938	1.200	0.385	0.325	15.61
30	208.0	7.54	53.112	81.596	1.200	0.443	0.375	15.34
31	220.0	9.76	89.013	136.751	1.200	0.468	0.410	12.45
32	74.5	11.80	52.599	13.206	1.200	0.392	0.413	-5.34
33	101.0	24.46	225.987	56.738	1.200	0.532	0.532	0.00
34	127.0	2.36	6.791	9.788	1.049	0.270	0.295	-9.17
35	134.0	2.80	9.598	13.833	1.049	0.285	0.313	-9.87
36	156.0	4.24	21.970	31.663	1.049	0.332	0.362	-8.96
37	168.0	5.66	39.141	56.409	1.049	0.357	0.400	-11.84
38	180.0	6.63	53.671	77.349	1.049	0.383	0.422	-10.26
39	131.0	1.67	7.838	10.083	1.216	0.279	0.234	16.17
40	160.0	3.40	32.440	41.736	1.216	0.340	0.299	12.18
41	183.0	4.78	64.200	82.598	1.216	0.389	0.337	13.56
42	185.0	6.11	104.711	134.717	1.216	0.394	0.366	6.92
43	171.0	4.22	52.421	67.443	1.216	0.364	0.323	11.19
44	164.0	3.32	32.440	41.736	1.216	0.349	0.297	14.80
45	142.0	1.97	11.416	14.688	1.216	0.302	0.248	17.91
46	136.0	5.15	13.258	20.147	1.180	0.289	0.322	-11.25

Table – 7.3.1 (contd.)

No.	a_c m^2/m^3	Re	We $\times 10^5$	Fr $\times 10^5$	σ/σ_c	a_c/a_t exp	a_c/a_t pred	% err
47	180.0	12.18	74.243	112.821	1.180	0.383	0.434	-13.34
48	140.0	4.26	13.374	19.184	1.148	0.298	0.318	-6.82
49	152.0	5.87	25.469	36.533	1.148	0.323	0.356	-10.02
50	180.0	8.98	59.542	85.408	1.148	0.383	0.412	-7.66
51	147.0	5.13	13.945	22.159	1.167	0.313	0.327	-4.46
52	160.0	6.52	22.489	35.736	1.167	0.340	0.355	-4.27
53	175.0	9.26	45.418	72.170	1.167	0.372	0.401	-7.70
54	181.0	11.22	66.671	105.942	1.167	0.385	0.429	-11.30
55	138.0	3.78	9.131	14.688	1.189	0.294	0.291	0.77
56	147.0	5.62	20.147	32.406	1.189	0.313	0.334	-6.86
57	173.0	7.45	35.384	56.914	1.189	0.368	0.369	-0.12
58	182.0	11.78	88.556	142.440	1.189	0.387	0.432	-11.59
59	64.0	34.19	283.004	33.224	1.213	0.492	0.574	-16.57
60	82.0	44.43	478.007	56.117	1.213	0.631	0.629	0.36
61	105.0	64.92	1020.460	119.801	1.213	0.808	0.717	11.24
62	127.0	95.65	2215.260	260.068	1.213	0.977	0.820	16.05
63	145.0	146.87	5222.913	613.163	1.213	1.115	0.952	14.68
64	79.2	1.48	1.075	0.817	1.200	0.240	0.205	14.77
65	105.6	4.52	10.041	7.633	1.200	0.320	0.301	5.80
66	125.4	7.77	29.686	22.567	1.200	0.380	0.364	4.26
67	155.1	15.57	119.173	90.595	1.200	0.470	0.463	1.49
68	178.2	28.62	402.524	305.999	1.200	0.540	0.572	-5.90
69	198.0	46.58	1066.123	810.469	1.200	0.600	0.677	-12.86
70	121.8	50.68	776.314	223.321	1.200	0.600	0.676	-12.66
71	148.1	101.35	3105.254	893.286	1.200	0.730	0.860	-17.84
72	76.0	1.11	0.869	0.878	1.230	0.205	0.184	10.31
73	114.0	2.39	4.053	4.095	1.230	0.308	0.241	21.89
74	133.0	4.94	17.281	17.459	1.230	0.359	0.310	13.89
75	148.2	6.76	32.326	32.660	1.230	0.401	0.345	13.85
76	171.0	9.88	69.124	69.837	1.230	0.462	0.394	14.82
77	114.0	2.40	4.629	4.431	1.213	0.308	0.246	20.07
78	125.4	3.89	12.208	11.685	1.213	0.339	0.291	14.02
79	144.4	6.86	37.952	36.326	1.213	0.390	0.355	9.10
80	163.4	11.47	106.052	101.509	1.213	0.442	0.424	3.99
81	182.4	19.86	318.190	304.559	1.213	0.493	0.513	-4.07
82	190.0	24.57	486.973	466.112	1.213	0.514	0.552	-7.56
83	66.0	10.07	24.080	6.280	1.189	0.347	0.384	-10.63
84	93.0	17.57	73.277	19.111	1.189	0.489	0.466	4.77
85	100.0	26.15	150.664	39.294	1.189	0.526	0.533	-1.21
86	108.0	31.36	216.800	56.543	1.189	0.568	0.567	0.18
87	132.0	38.50	364.254	95.000	1.189	0.695	0.613	11.73
88	130.0	57.74	819.572	213.750	1.189	0.684	0.706	-3.16
89	130.0	44.82	493.698	128.760	1.189	0.684	0.646	5.52
90	27.0	8.35	17.979	4.657	2.599	0.142	0.153	-7.34
91	36.0	15.84	64.677	16.752	2.599	0.189	0.190	-0.53
92	169.0	2.47	6.555	9.738	1.027	0.367	0.305	17.10
93	206.0	3.72	14.811	22.004	1.027	0.448	0.351	21.66
94	227.0	4.95	26.219	38.953	1.027	0.493	0.387	21.50
95	258.0	6.18	40.863	60.709	1.027	0.561	0.418	25.41
96	268.0	7.42	58.992	87.644	1.027	0.583	0.446	23.47
97	284.0	9.89	104.875	155.811	1.027	0.617	0.493	20.20

Table - 7.3.1 (contd.)

No.	a_c m^2/m^3	Re	We $\times 10^5$	Fr $\times 10^5$	σ/σ_c	a_c/a_t exp	a_c/a_t pred	% err
98	72.6	1.31	1.084	0.842	1.215	0.220	0.196	10.77
99	107.3	4.18	11.097	8.620	1.215	0.325	0.294	9.57
100	136.0	8.36	44.389	34.482	1.215	0.412	0.374	9.30
101	208.0	16.24	167.698	130.269	1.215	0.630	0.471	25.31
102	24.0	1.31	1.084	0.842	2.675	0.073	0.082	-12.90
103	43.0	4.18	11.097	8.620	2.675	0.130	0.123	5.65
104	49.5	8.36	44.389	34.482	2.675	0.150	0.156	-4.25
105	65.4	16.24	167.698	130.269	2.675	0.198	0.197	0.63
106	33.0	1.31	1.084	0.842	2.245	0.100	0.100	0.00
107	46.5	4.18	11.097	8.620	2.245	0.141	0.149	-5.85
108	59.6	8.36	44.389	34.482	2.245	0.181	0.190	-5.04
109	81.0	16.24	167.698	130.269	2.245	0.245	0.239	2.66
110	107.5	32.64	677.320	526.148	2.245	0.326	0.304	6.56
111	92.7	3.68	14.536	21.596	1.641	0.201	0.209	-3.49
112	107.4	4.91	25.803	38.335	1.641	0.234	0.230	1.37
113	121.9	6.17	40.825	60.653	1.641	0.265	0.249	5.86
114	131.8	7.46	59.560	88.487	1.641	0.286	0.266	7.05
115	60.7	1.43	1.230	0.860	1.215	0.194	0.202	-4.04
116	92.0	4.29	11.074	7.739	1.215	0.294	0.295	-0.51
117	112.7	8.57	44.295	30.955	1.215	0.360	0.376	-4.40
118	102.1	8.88	45.909	29.867	1.215	0.338	0.380	-12.34
119	140.4	15.99	148.745	96.770	1.215	0.465	0.466	-0.12
120	153.4	23.26	314.700	204.737	1.215	0.508	0.530	-4.38
121	35.5	2.76	4.735	3.524	2.675	0.110	0.106	3.28
122	43.6	4.85	14.606	10.870	2.675	0.135	0.129	4.25
123	33.6	1.53	1.319	0.802	2.245	0.115	0.104	9.22
124	44.3	4.59	11.870	7.220	2.245	0.152	0.153	-0.81
125	57.8	9.19	47.481	28.878	2.245	0.198	0.195	1.73
126	28.2	1.54	1.323	0.799	2.245	0.097	0.105	-7.90
127	50.6	9.22	47.644	28.779	2.245	0.174	0.195	-11.98
128	59.3	16.60	154.367	93.246	2.245	0.204	0.239	-17.17
129	81.5	24.14	326.596	197.280	2.245	0.280	0.272	2.91
130	28.0	1.44	1.242	0.852	2.245	0.090	0.103	-13.71
131	56.0	8.65	44.724	30.659	2.245	0.181	0.191	-5.88
132	77.5	15.58	144.906	99.334	2.245	0.250	0.235	6.19
133	93.0	22.66	306.579	210.161	2.245	0.300	0.267	10.97
134	23.6	1.55	1.337	0.791	2.245	0.082	0.105	-27.98
135	53.0	9.32	48.141	28.483	2.245	0.184	0.195	-6.12
136	67.0	16.77	155.975	92.284	2.245	0.233	0.239	-2.94
137	51.4	1.53	1.319	0.802	1.372	0.176	0.180	-2.21
138	77.1	4.59	11.870	7.220	1.372	0.264	0.263	0.21
139	97.8	9.19	47.481	28.878	1.372	0.335	0.335	0.00
140	44.5	1.54	1.323	0.799	1.372	0.153	0.180	-17.77
141	137.9	16.60	154.367	93.246	1.372	0.474	0.411	13.22
142	116.4	24.14	326.596	197.280	1.372	0.400	0.468	-17.09
143	114.0	8.65	44.724	30.659	1.372	0.368	0.329	10.42
144	137.6	15.58	144.906	99.334	1.372	0.444	0.404	8.99
145	140.7	22.69	307.289	210.647	1.372	0.454	0.460	-1.40
146	95.0	9.32	48.141	28.483	1.372	0.330	0.336	-1.97
147	105.7	16.77	155.975	92.284	1.372	0.367	0.412	-12.38

Table - 7.3.1 (contd.)

No.	a_c m^2/m^3	Re	We $\times 10^5$	Fr $\times 10^5$	σ/σ_c	a_c/a_t exp	a_c/a_t pred	% err
148	109.7	8.44	43.599	31.450	1.372	0.345	0.327	5.19
149	135.0	15.19	141.261	101.897	1.372	0.425	0.401	5.53
150	150.0	22.09	298.866	215.584	1.372	0.472	0.457	3.17
151	43.7	3.91	9.975	5.593	2.290	0.151	0.143	5.22
152	52.8	7.70	38.704	21.703	2.290	0.182	0.181	0.91
153	61.4	11.99	93.961	52.689	2.290	0.212	0.211	0.57
154	71.2	14.99	146.814	82.327	2.290	0.246	0.228	7.33
155	199.0	16.16	259.931	267.577	1.068	0.510	0.557	-9.07
156	175.5	10.84	116.943	120.383	1.068	0.450	0.485	-7.67
157	144.0	5.91	34.793	35.816	1.068	0.369	0.393	-6.33
158	123.0	3.35	11.181	11.510	1.068	0.315	0.322	-2.23
159	215.8	14.72	312.465	315.223	1.068	0.553	0.551	0.44
160	201.0	11.75	198.856	200.611	1.068	0.515	0.509	1.17
161	171.0	7.11	72.939	73.583	1.068	0.438	0.428	2.38
162	151.0	4.96	35.503	35.816	1.068	0.387	0.378	2.44
163	132.8	3.14	14.241	14.366	1.068	0.341	0.322	5.33
164	161.0	5.32	29.843	43.396	1.008	0.345	0.406	-17.64
165	176.0	6.22	40.786	59.309	1.008	0.377	0.428	-13.61
166	188.0	7.12	53.297	77.503	1.008	0.403	0.449	-11.41
167	204.0	8.89	83.277	121.098	1.008	0.437	0.485	-10.94

Table - (7.3.2)

Statistical analysis for different correlations of a_c

Correlation Structure : $a_c / a_t = C \cdot Re^{\alpha} \cdot We^{\beta} \cdot Fr^{\gamma} \cdot (\sigma/\sigma_c)^{\delta}$.

No.	C	α	β	γ	δ	% E_{av}	% E_{abs}	% S_{dev}

Case 1 : - Multiple Linear Regression

Numerical Method : Gauss Jordan algorithm.

1	1.57	0.194	0.075	3.39E-06	-1.159	-0.47	8.11	4.88.

Numerical Method : Gauss Seidel algorithm.

Convergence criteria $\varepsilon = 0.001$

2	0.589	0.1918	0.0698	0.0087	-1.148	-0.645	8.83	4.938.

Convergence criteria $\varepsilon = 0.0001$

3	0.573	0.1935	0.0745	0.001	-1.158	-0.59	8.83	4.89.

Case 2 :- Optimisation by the D.S.C. - Powell algorithm.

Initialisation were based on arbitary guesses of indices, α β, γ, δ, and C were fed as 0.2, 0.07, 0.002, -1.1, 0.6.(Clue for guesses were taken from the values obtained in previous steps)

Direction of search sequence α, β, δ, γ, C. respectively.

4	0.5186	0.2205	0.035	0.029	-1.314	-0.6	10.24	5.21.

Direction of search sequence changed to C, β, δ, α, γ. Initialisation as in step no 4.

5	0.516	0.2079	0.0393	0.021	-1.263	-1.02	9.76	5.2.

Direction of search sequence changed to C, β, δ, α, γ. Initialisation as in step no 4. γ value fixed as 0.002.

6	0.400	0.244	0.036	0.002	-1.293	0.086	9.7	5.04

Direction of search sequence changed to δ, C, β, α, γ. Initialisation as in step no. 4.

7	0.517	0.2209	0.0355	0.0276	-1.333	-0.33	10.41	5.22.

Table - 7.3.2 (contd.)

No.	C	α	β	γ	δ	% E_{av}	% E_{abs}	% S_{dev}
Direction of search sequence changed to β, C, δ, α, γ. Initialisation as in step no. 4.								
8	0.515	0.23	0.042	0.0238	-1.3275	0.74	10.37	5.12.
Case 3 : - Optimisation by the Modified Simplex algorithm of Nelder and Mead								
All parameters are iterated, base values as obtained from step no 3. Each indice value perturbed 50 % at a time.								
9	0.6212	0.1807	0.074	0.013	-1.09	1.57	8.51	5.04.
β value fixed as 0.002 . Other parameters iterated as in step 9.								
10*	0.455	0.227	0.058	0.002	-1.104	1.38	8.25	4.896.
γ and δ values fixed as 0.002 and -0.442. Other parameters iterated as in step 9.								
11	0.898	0.101	0.133	0.002	-0.442	-3.69	17.79	7.1.
C fixed as 1.43 and γ fixed as 0.002. Other parameters iterated as in step no. 9.								
12	1.43	0.049	0.159	0.002	-1.069	1.1	9.138	5.57.
β and γ fixed as 0.165 and 0.002 respectively , as in wetted surface area correlations.								
13	1.49	0.051	0.165	0.002	-1.063	1.25	9.196	5.49.

Note : The values of indices in the finalised generalised correlation are as per regression step marked by (*)

prefixing the values of some indices, yielded the following equation:-

$$a_c/a_t = 0.455\ (Re)^{0.227}\ (We)^{0.058}\ (Fr)^{0.002}\ (\sigma / \sigma_c)^{-1.104} \quad (7.10)$$

wherein the values of indices of all the dimensionless numbers inclusive of proportionality constant are such that the correlation predicts the values of a_c with least amount of error.

For obtaining equation (7.10) regression of the data on a_c was performed as per step (10) and the values of E_{avg}, E_{abs} and S_{dev} were 1.38 %, 8.25 % and 4.9 % respectively. Thus, the values of E_{abs} futher decreased to 8.25 % (regression step - 10) in comparison to 10.4 % obtained during the regression step (7). This clearly indicates that the different optimization methodologies sometimes do give different statistical analysis as well as data fit. Hence one has to be careful while selecting a methodology for performing mathematical modelling of data.

Further in the regression step (11), the value of the index of (σ / σ_c) was prefixed to -0.442 which was similar to the value obtained for the cases of a_w and a_p. However, under these conditions the algorithm failed to minimise the error by altering other indices appropriately. The resulting equation based on the regression step (11), yielded the values of % E_{avg}, % E_{abs} and % S_{dev} as -3.69, 17.79 and 7.1 respectively. This statistical analysis for the regression step (11) was very much inferior in comparison to the statistical analysis for the regression step (10). Except for the regression step (11), all the other regression steps in Table (7.3.2) yielded nearly identical values of the index for the (σ / σ_c) parameter. Thus it can be concluded that the (σ / σ_c) parameter is the dominant parameter affecting the values of a_c in comparison to the other parameters. The effect of parameters (σ / σ_c) and Re on the values of a_c appears to be more pronounced than that of a_w and a_p, as could be seen from the indices of these parameters in equations (7.3), (7.7) and (7.10) respectively.

7.3.3 Comparions between experimental values (based on data banks) and predicted values of a_c :

The values of (a_c/a_t) obtained from the data bank and the values of (a_c/a_t) predicted by using the correlation [Equation (7.10)] are tabulated in Table (7.3.3) and are plotted in Figure (7.3). The detailed statistical analysis of the correlation [Equation (7.10)] can be described as follows :

(i) The total number of data points used in the correlation are 167 with 32 different systems/variations included.

(ii) The values of % E_{avg}, % E_{abs} and % S_{dev} were 1.38, 8.25 and 4.89 respectively.

(iii) From the 167 data points 94 % of the predicted values of a_c were within ± 20 % of the experimental data values, 85 % were within ± 15 %, 60 % were within ± 10 % and 36 % were within ± 5 %.

Figure (7.3), shows a parity plot of equation (7.10) wherein the values of $(a_c/a_t)_{pred}$ have been plotted versus $(a_c/a_t)_{exp}$. The satisfactory correlation fit in Figure (7.3) clearly reflects that

Table - (7.3.3)

Comparison between experimental values based on data bank and predicted values of a_c

No.	a_c m^2/m^3	a_c/a_t exp.	a_c/a_t This work	% err	a_c/a_t Puranik & Vogelpohl	% err
1	106.0	0.286	0.266	7.02	0.304	-6.09
2	134.0	0.362	0.308	14.84	0.304	16.08
3	141.0	0.381	0.389	-1.98	0.373	2.14
4	154.0	0.416	0.448	-7.66	0.423	-1.62
5	82.0	0.222	0.222	0.00	0.246	-11.18
6	97.0	0.262	0.284	-8.19	0.305	-16.53
7	120.0	0.324	0.326	-0.42	0.345	-6.45
8	127.5	0.345	0.361	-4.69	0.378	-9.67
9	144.5	0.391	0.390	0.24	0.405	-3.59
10	63.0	0.485	0.535	-10.46	0.511	-5.36
11	78.0	0.600	0.587	2.19	0.554	7.68
12	92.7	0.713	0.689	3.35	0.639	10.45
13	110.0	0.846	0.746	11.78	0.685	19.01
14	119.0	0.915	0.783	14.48	0.715	21.92
15	128.0	0.272	0.270	0.73	0.328	-20.33
16	156.0	0.332	0.331	0.27	0.392	-18.11
17	172.0	0.366	0.377	-3.06	0.440	-20.23
18	126.0	0.268	0.258	3.71	0.291	-8.59
19	142.0	0.302	0.301	0.29	0.334	-10.46
20	154.0	0.328	0.323	1.52	0.355	-8.23
21	168.0	0.357	0.349	2.27	0.380	-6.43
22	179.0	0.381	0.371	2.50	0.402	-5.44
23	187.0	0.398	0.392	1.38	0.422	-5.97
24	190.0	0.404	0.413	-2.13	0.441	-9.11
25	141.0	0.300	0.252	15.91	0.285	4.92
26	178.0	0.379	0.321	15.37	0.353	6.91
27	206.0	0.438	0.370	15.57	0.400	8.66
28	143.0	0.304	0.257	15.57	0.290	4.73
29	181.0	0.385	0.325	15.61	0.357	7.33
30	208.0	0.443	0.375	15.34	0.405	8.54
31	220.0	0.468	0.410	12.45	0.438	6.39
32	74.5	0.392	0.413	-5.34	0.412	-5.01
33	101.0	0.532	0.532	0.00	0.515	3.12
34	127.0	0.270	0.295	-9.17	0.301	-11.33
35	134.0	0.285	0.313	-9.87	0.317	-11.27
36	156.0	0.332	0.362	-8.96	0.360	-8.53
37	168.0	0.357	0.400	-11.84	0.394	-10.12
38	180.0	0.383	0.422	-10.26	0.413	-7.88
39	131.0	0.279	0.234	16.17	0.294	-5.58
40	160.0	0.340	0.299	12.18	0.366	-7.51
41	183.0	0.389	0.337	13.56	0.406	-4.38
42	185.0	0.394	0.366	6.92	0.438	-11.30
43	171.0	0.364	0.323	11.19	0.394	-8.17
44	164.0	0.349	0.297	14.80	0.366	-4.78
45	142.0	0.302	0.248	17.91	0.311	-3.09
46	136.0	0.289	0.322	-11.25	0.332	-14.84

Table - 7.3.3 (contd.)

No.	a_c m^2/m^3	a_c/a_t exp.	a_c/a_t This work	% err This work	a_c/a_t Puranik & Vogelpohl	% err Puranik & Vogelpohl
47	180.0	0.383	0.434	-13.34	0.433	-13.04
48	140.0	0.298	0.318	-6.82	0.332	-11.39
49	152.0	0.323	0.356	-10.02	0.366	-13.26
50	180.0	0.383	0.412	-7.66	0.417	-8.96
51	147.0	0.313	0.327	-4.46	0.335	-7.17
52	160.0	0.340	0.355	-4.27	0.361	-5.96
53	175.0	0.372	0.401	-7.70	0.402	-7.91
54	181.0	0.385	0.429	-11.30	0.426	-10.67
55	138.0	0.294	0.291	0.77	0.312	-6.22
56	147.0	0.313	0.334	-6.86	0.352	-12.59
57	173.0	0.368	0.369	-0.12	0.384	-4.31
58	182.0	0.387	0.432	-11.59	0.442	-14.15
59	64.0	0.492	0.574	-16.57	0.537	-9.06
60	82.0	0.631	0.629	0.36	0.582	7.75
61	105.0	0.808	0.717	11.24	0.654	19.06
62	127.0	0.977	0.820	16.05	0.736	24.63
63	145.0	1.115	0.952	14.68	0.840	24.70
64	79.2	0.240	0.205	14.77	0.225	6.10
65	105.6	0.320	0.301	5.80	0.318	0.75
66	125.4	0.380	0.364	4.26	0.375	1.29
67	155.1	0.470	0.463	1.49	0.464	1.21
68	178.2	0.540	0.572	-5.90	0.560	-3.64
69	198.0	0.600	0.677	-12.86	0.650	-8.32
70	121.8	0.600	0.676	-12.66	0.625	-4.21
71	148.1	0.730	0.860	-17.84	0.774	-6.02
72	76.0	0.205	0.184	10.31	0.216	-4.94
73	114.0	0.308	0.241	21.89	0.273	11.38
74	133.0	0.359	0.310	13.89	0.341	5.10
75	148.2	0.401	0.345	13.85	0.376	6.24
76	171.0	0.462	0.394	14.82	0.422	8.69
77	114.0	0.308	0.246	20.07	0.279	9.58
78	125.4	0.339	0.291	14.02	0.323	4.60
79	144.4	0.390	0.355	9.10	0.385	1.40
80	163.4	0.442	0.424	3.99	0.451	-2.02
81	182.4	0.493	0.513	-4.07	0.533	-8.19
82	190.0	0.514	0.552	-7.56	0.569	-10.87
83	66.0	0.347	0.384	-10.63	0.369	-6.33
84	93.0	0.489	0.466	4.77	0.438	10.49
85	100.0	0.526	0.533	-1.21	0.490	6.87
86	108.0	0.568	0.567	0.18	0.518	8.82
87	132.0	0.695	0.613	11.73	0.560	19.39
88	130.0	0.684	0.706	-3.16	0.634	7.30
89	130.0	0.684	0.646	5.52	0.587	14.24
90	27.0	0.142	0.153	-7.34	0.306	-115.16
91	36.0	0.189	0.190	-0.53	0.372	-96.41
92	169.0	0.367	0.305	17.10	0.301	18.03
93	206.0	0.448	0.351	21.66	0.341	23.79
94	227.0	0.493	0.387	21.50	0.373	24.50
95	258.0	0.561	0.418	25.41	0.399	28.89
96	268.0	0.583	0.446	23.47	0.422	27.58
97	284.0	0.617	0.493	20.20	0.461	25.35

Table - 7.3.3 (contd.)

No.	a_c m^2/m^3	a_c/a_t exp.	a_c/a_t This work	% err	a_c/a_t Puranik & Vogelpohl	% err
98	72.6	0.220	0.196	10.77	0.224	-1.81
99	107.3	0.325	0.294	9.57	0.320	1.51
100	136.0	0.412	0.374	9.30	0.396	3.91
101	208.0	0.630	0.471	25.31	0.486	22.95
102	24.0	0.073	0.082	-12.90	0.194	-166.75
103	43.0	0.130	0.123	5.65	0.277	-112.78
104	49.5	0.150	0.156	-4.25	0.343	-128.67
105	65.4	0.198	0.197	0.63	0.421	-112.25
106	33.0	0.100	0.100	0.00	0.200	-100.28
107	46.5	0.141	0.149	-5.85	0.286	-103.14
108	59.6	0.181	0.190	-5.04	0.354	-96.07
109	81.0	0.245	0.239	2.66	0.434	-76.92
110	107.5	0.326	0.304	6.56	0.538	-65.17
111	92.7	0.201	0.209	-3.49	0.313	-55.10
112	107.4	0.234	0.230	1.37	0.341	-46.14
113	121.9	0.265	0.249	5.86	0.366	-38.22
114	131.8	0.286	0.266	7.05	0.388	-35.44
115	60.7	0.194	0.202	-4.04	0.229	-17.86
116	92.0	0.294	0.295	-0.51	0.320	-8.96
117	112.7	0.360	0.376	-4.40	0.396	-10.09
118	102.1	0.338	0.380	-12.34	0.399	-17.99
119	140.4	0.465	0.466	-0.12	0.478	-2.72
120	153.4	0.508	0.530	-4.38	0.536	-5.49
121	35.5	0.110	0.106	3.28	0.243	-121.45
122	43.6	0.135	0.129	4.25	0.289	-114.34
123	33.6	0.115	0.104	9.22	0.207	-79.83
124	44.3	0.152	0.153	-0.81	0.290	-91.11
125	57.8	0.198	0.195	1.73	0.359	-81.21
126	28.2	0.097	0.105	-7.90	0.207	-113.66
127	50.6	0.174	0.195	-11.98	0.359	-106.41
128	59.3	0.204	0.239	-17.17	0.430	-110.95
129	81.5	0.280	0.272	2.91	0.482	-72.20
130	28.0	0.090	0.103	-13.71	0.205	-126.73
131	56.0	0.181	0.191	-5.88	0.355	-96.51
132	77.5	0.250	0.235	6.19	0.425	-70.07
133	93.0	0.300	0.267	10.97	0.477	-59.00
134	23.6	0.082	0.105	-27.98	0.207	-153.13
135	53.0	0.184	0.195	-6.12	0.360	-95.38
136	67.0	0.233	0.239	-2.94	0.431	-85.12
137	51.4	0.176	0.180	-2.21	0.226	-28.58
138	77.1	0.264	0.263	0.21	0.317	-20.14
139	97.8	0.335	0.335	0.00	0.392	-17.14
140	44.5	0.153	0.180	-17.77	0.226	-48.10
141	137.9	0.474	0.411	13.22	0.470	0.78
142	116.4	0.400	0.468	-17.09	0.528	-31.88
143	114.0	0.368	0.329	10.42	0.388	-5.58
144	137.6	0.444	0.404	8.99	0.465	-4.77
145	140.7	0.454	0.460	-1.40	0.522	-14.99
146	95.0	0.330	0.336	-1.97	0.393	-19.22
147	105.7	0.367	0.412	-12.38	0.471	-28.34

Table - 7.3.3 (contd.)

No.	a_c m^2/m^3	a_c/a_t exp.	a_c/a_t This work	% err	a_c/a_t Puranik & Vogelpohl	% err
148	109.7	0.345	0.327	5.19	0.387	-12.05
149	135.0	0.425	0.401	5.53	0.463	-9.06
150	150.0	0.472	0.457	3.17	0.519	-10.12
151	43.7	0.151	0.143	5.22	0.280	-86.22
152	52.8	0.182	0.181	0.91	0.345	-89.48
153	61.4	0.212	0.211	0.57	0.396	-86.79
154	71.2	0.246	0.228	7.33	0.424	-72.54
155	199.0	0.510	0.557	-9.07	0.527	-3.25
156	175.5	0.450	0.485	-7.67	0.466	-3.57
157	144.0	0.369	0.393	-6.33	0.387	-4.79
158	123.0	0.315	0.322	-2.23	0.325	-3.06
159	215.8	0.553	0.551	0.44	0.538	2.80
160	201.0	0.515	0.509	1.17	0.502	2.64
161	171.0	0.438	0.428	2.38	0.430	1.89
162	151.0	0.387	0.378	2.44	0.385	0.52
163	132.8	0.341	0.322	5.33	0.335	1.68
164	161.0	0.345	0.406	-17.64	0.382	-10.67
165	176.0	0.377	0.428	-13.61	0.400	-6.21
166	188.0	0.403	0.449	-11.41	0.417	-3.60
167	204.0	0.437	0.485	-10.94	0.447	-2.24

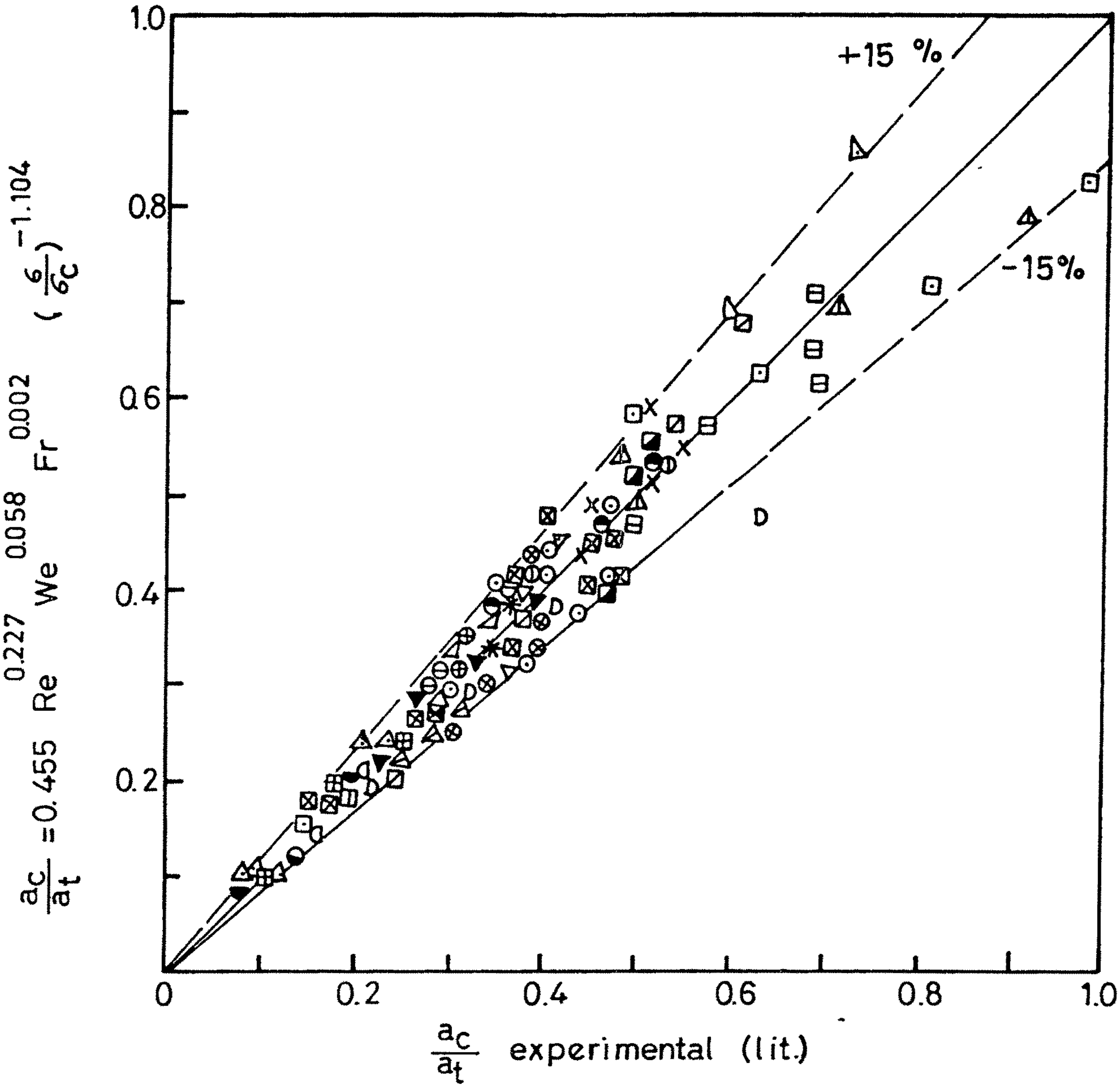

Fig. 7.3 EFFECTIVE INTERFACIAL AREA DURING ABSORPTION WITH CHEMICAL REACTION.
COMPARISON OF PREDICTED vs. EXPERIMENTAL (LIT.) DATA.

LEGENDS FOR FIG. 7.3

Data No.	Relevant Information	Symbol
1	Danckwerts (19), CO_2-Na Buffer, C.R.R., 13mm	◘
2-4	Vassilatos (20), CO_2-aq.NH_3, C.R.R., 13mm.	∇
5-9	Richards (21), CO_2-Na Buffer, C.R.R., 13mm.	▼
10-14	Danckwerts (22), CO_2-K Buffer, C.R.R., 38mm.	Δ
15-17	Gehlawat (23), isobutylene-11.5 M H_2SO_4, C.R.R.,9.5mm.	*
18-33	Vidwans (24), CO_2-NaOH, C.R.R., 9.5mm, 25mm.	O, Φ
34-38	Vidwans (24), CO_2-MEA, C.R.R, 9.5mm.	θ
39-47	Jhaveri (25), O_2-aq CuCl., C.R.R., 9.5mm.	⊗
48-50	Jhaveri (25), O_2-aq CuCl + 5 M HCl, C.R.R., 9.5mm.	⊕
51-58	Jhaveri (25), O_2-Na dithionite, C.R.R, 9.5mm.	⊿
59-63	Danckwerts (27), Sulphite oxidation, C.R.R., 38mm.	□
64-69	Onda (28), Sulphite oxidation, C.R.R., 15mm.	⊘
70-71	DeWaal (29), Sulphite oxidation, C.R.R., 25mm.	◺
72-82	Puranik (30), CO_2-NaOH, C.R.R., 13mm.	◪
83-91	Sahay (31), O_2-Na dithionite, d_p = 25mm, C.R.R. and Polypropylene R.R.	⊟, ◫
92-97	Andrieu (32), Sulphite oxidation, Pyrex R.R., 10 mm.	◩
98-110	Linek (33) Sulphite oxidation, d_p = 15mm, C.R.R., Polypropylene R.R., Polyethylene R.R.	D, ▼, ⊞
111-114	Andrieu (34), Sulphite oxidation, Silicone Coated R.R. 10mm.	Δ
115-150	Linek (35), Sulphite oxidation, d_p=15mm, Polypropylene R.R. C.R.R., Polyethylene R.R. and Hydrophilised R.R.	◒, ◒, Δ, ⊠
151-154	Alper (36), CO_2-K Buffer, Polyethylene R.R., 16mm.	ɑ
155-163	Rizzuti (37), CO_2-K Buffer, Glass R.R., 10mm.	X
163-167	Augugliaro (39), CO_2-K Buffer, Steel.R.R., 10mm.	⊙

equation (7.10) can correlate satisfactorily all the data obtained from various sources covering a wide range of variables as mentioned earlier.

No generalised correlation is available in the literature for predicting the values of a_c, except that of Puranik and Vogelpohl (106) [Equation (2.10)]. The values of (a_c/a_t) obtained by using this correlation are also reported in Table (7.3.3). The detailed statistical analysis of correlation by Puranik and Vogelpohl can be described as follows:

(i) The values of % E_{avg}, % E_{abs} and % S_{dev} were -21.3, 27.5 and 8.8 respectively.

(ii) From the 167 data points 73 % of the predicted values of a_c were within ± 20 % of the experimental data values, 68 % were within ± 15 % and only 50 % were within ± 10 %.

The comparison of the statistical analysis for both the correlations reveals that the value of % E_{abs}(also % E_{avg}) for the correlation of Puranik and Vogelpohl is substantially higher than that for correlation developed in this investigation being 27.5 and 8.25 respectively.

During the period when the correlation for predicting the values of (a_c/a_t) was proposed by Puranik and Vogelpohl, the data bank of (a_c/a_t) for plastic packings was not available in the literature, that is why the correlation of Puranik and Vogelpohl totally fails to predict the values of (a_c/a_t) for plastic packings within reasonable limits of accuracy. Practically for all the data of (a_c/a_t) for plastic packings, the predicted values are over 50 % higher than the experimenally obtained values with the values of maximum error as high as -166 %; Whereas the maximum error in the correlation [Equation (7.10)] developed in this investigation is only -28 %.

Since the generalised correlation proposed by Puranik and Vogelpohl happens to be a correlation to be utilised also for predicting the value of (a_w/a_t), the data fit only for the values of a_c might have been inferior. Further, the index of the dominant parameter (σ / σ_c) probably would not have been appropriately optimised in that correlation. Hence, the correlation proposed in this investigations [Equation (7.10)] is expected to be superior in comparision to the existing generalised correlation of Puranik and Vogelpohl.

7.4.0 RESULTS AND DISCUSSION FOR STATIC AREA (a_{st}) :

As has been already discussed in Chapter (6) : Mathematical modelling of effective interfacial areas and mass transfer coefficients; equation (6.4) can be used to estimate the values of static area. The use of equation (6.4) requires the knowledge of a_w and a_p under otherwise identical conditions. However, it is observed that the experimental values of a_w or a_p reported in the literature are not available under otherwise idential conditions. Hence, the following approaches can be used for estimating the values of a_{st} :-

APPROACH (I) : Using the data bank of a_p and obtaining the values of

a_w under otherwise identical conditions by use of generalised correlation developed in this investigation i.e.,

$$a_{st} = a_w \text{ by correlation} - a_p \text{ from data bank} \qquad (7.11)$$

APPROACH (II) : Using the data bank of a_w and obtaining the values of a_p under otherwise identical conditions by use of generalised correlation i.e.,

$$a_{st} = a_w \text{ from data bank} - a_p \text{ by correlation} \qquad (7.12)$$

7.4.1 Results for a_{st} by approach (I) : Use of equation (7.11) :-

The generalised correlation for a_w/a_t [Equation (7.3)] developed in this investigation could be used conveniently to obtain the value of a_w under otherwise identical conditions mentioned for the data bank of experimental values of a_p. The results obtained for the observed values of a_{st} by approach (I) are reported in Table (7.4.1) which consists of 100 data points covering systems for physical absorption such as ammonia - water, CO_2 - water, CO_2 - methanol, CO_2 - cane sugar solutions, methanol vapour - water etc. and includes 18 variations. These observed values of a_{st} could be used appropriately for analysing the effect of different variables on the values of a_{st}.

7.4.2 Critical analysis of data and mathematical modelling for a_{st} :-

As has been discussed already, the values of a_{st} get affected by the liquid flow rate (L), the packing size (d_p) and its wettability and the physical properties of the liquid/absorption media like density, viscosity and surface tension etc.

Table - (7.4.1)

Observed values of static area during absorption (a_{st}) based on $(a_p/a_t)_{exp}$

No	T	a_t	ρ_L	μ_L	σ	L	a_p exp.	a_w pred.	a_{st} obs.
	^oC	m^2/m^3	kg/m^3	mNs/m^2	mN/m	kg/m^2s	m^2/m^3		
1	20.0	195.0	998.2	1.008	72.8	0.678	28.1	45.9	17.8
2	20.0	195.0	998.2	1.008	72.8	1.350	39.6	57.8	18.2
3	20.0	195.0	998.2	1.008	72.8	2.034	48.2	66.4	18.1
4	20.0	195.0	998.2	1.008	72.8	5.400	68.4	92.1	23.7
5	20.0	195.0	998.2	1.008	72.8	6.103	67.8	95.9	28.1
6	20.0	195.0	998.2	1.008	72.8	6.800	78.0	99.5	21.5
7	20.0	195.0	998.2	1.008	72.8	0.111	12.2	25.0	12.8
8	20.0	195.0	998.2	1.008	72.8	0.204	11.6	30.7	19.1
9	20.0	195.0	998.2	1.008	72.8	0.312	14.5	35.4	20.9
10	20.0	195.0	998.2	1.008	72.8	0.440	21.0	39.7	18.7
11	20.0	195.0	998.2	1.008	72.8	0.622	19.4	44.6	25.2
12	20.0	195.0	998.2	1.008	72.8	1.392	30.8	58.4	27.6
13	20.0	195.0	998.2	1.008	72.8	4.716	52.2	88.0	35.8
14	20.0	195.0	998.2	1.008	72.8	7.947	72.0	104.8	32.8
15	20.0	195.0	998.2	1.008	72.8	0.146	16.0	27.4	11.4
16	20.0	195.0	998.2	1.008	72.8	0.358	19.7	37.0	17.3
17	20.0	195.0	998.2	1.008	72.8	0.598	26.6	44.0	17.4
18	20.0	195.0	998.2	1.008	72.8	1.240	33.5	56.2	22.7
19	20.0	195.0	998.2	1.008	72.8	2.043	45.4	66.5	21.0
20	20.0	195.0	998.2	1.008	72.8	3.116	57.2	76.6	19.3
21	20.0	195.0	998.2	1.008	72.8	6.265	70.9	96.8	25.9
22	20.0	348.0	998.2	1.008	72.8	0.156	9.9	45.5	35.6
23	20.0	348.0	998.2	1.008	72.8	0.302	15.0	56.8	41.8
24	20.0	348.0	998.2	1.008	72.8	0.585	22.3	70.9	48.5
25	20.0	348.0	998.2	1.008	72.8	0.725	32.5	76.2	43.6
26	20.0	348.0	998.2	1.008	72.8	0.927	30.1	82.7	52.6
27	20.0	348.0	998.2	1.008	72.8	1.514	30.1	97.5	67.4
28	20.0	348.0	998.2	1.008	72.8	3.188	54.4	125.2	70.8
29	20.0	348.0	998.2	1.008	72.8	5.131	63.5	146.9	83.4
30	20.0	348.0	998.2	1.008	72.8	5.846	58.8	153.4	94.7
31	20.0	348.0	998.2	1.008	72.8	7.947	75.5	170.1	94.6
32	20.0	348.0	998.2	1.008	72.8	0.203	13.9	49.7	35.8
33	20.0	348.0	998.2	1.008	72.8	0.529	27.7	68.5	40.8
34	20.0	348.0	998.2	1.008	72.8	0.845	32.3	80.2	47.9
35	20.0	348.0	998.2	1.008	72.8	2.043	43.9	107.8	63.9
36	20.0	348.0	998.2	1.008	72.8	4.235	64.4	137.7	73.3
37	15.0	348.0	796.0	0.669	23.0	0.290	17.5	117.1	99.7
38	15.0	348.0	796.0	0.669	23.0	0.409	37.7	131.5	93.9
39	15.0	348.0	796.0	0.669	23.0	0.539	40.6	144.3	103.6
40	15.0	330.0	999.0	1.144	73.5	0.280	21.8	52.6	30.8
41	15.0	330.0	999.0	1.144	73.5	0.550	29.6	66.0	36.4
42	15.0	330.0	999.0	1.144	73.5	2.220	58.7	105.4	46.7
43	15.0	330.0	999.0	1.144	73.5	2.780	64.0	113.6	49.7
44	15.0	330.0	999.0	1.144	73.5	5.500	87.4	142.9	55.5
45	25.0	330.0	787.7	0.523	21.9	0.280	54.6	114.4	59.8

Table - 7.4.1 (contd.)

No	T	a_t	ρ_L	μ_L	σ	L	a_p exp.	a_w pred.	a_{st} obs.
	^oC	m^2/m^3	kg/m^3	mNs/m^2	mN/m	kg/m^2s	m^2/m^3		
46	25.0	330.0	787.7	0.523	21.9	0.550	65.5	143.4	77.9
47	25.0	330.0	787.7	0.523	21.9	0.830	71.8	164.6	92.9
48	25.0	330.0	787.7	0.523	21.9	1.120	93.6	182.1	88.5
49	25.0	330.0	787.7	0.523	21.9	1.670	109.2	208.2	99.0
50	25.0	330.0	787.7	0.523	21.9	2.220	124.8	229.0	104.2
51	25.0	330.0	.787.7	0.523	21.9	2.780	131.0	247.0	115.9
52	25.0	330.0	787.7	0.523	21.9	5.500	188.8	310.5	121.7
53	25.0	207.0	787.7	0.523	21.9	0.550	64.2	97.1	33.0
54	25.0	207.0	787.7	0.523	21.9	0.830	82.8	111.5	28.7
55	25.0	207.0	787.7	0.523	21.9	1.120	89.0	123.3	34.3
56	25.0	207.0	787.7	0.523	21.9	1.670	105.6	141.0	35.4
57	25.0	207.0	787.7	0.523	21.9	2.220	124.2	155.1	30.9
58	25.0	330.0	894.0	1.427	30.0	2.780	109.2	199.4	90.2
59	25.0	330.0	953.0	1.600	40.0	2.780	90.5	165.6	75.2
60	25.0	330.0	981.0	1.185	55.0	2.780	78.0	135.9	57.9
61	15.0	330.0	1100.0	3.500	70.0	1.390	49.9	91.1	41.2
62	15.0	330.0	1100.0	3.500	70.0	2.780	65.5	115.0	49.5
63	15.0	330.0	1100.0	3.500	70.0	5.560	90.5	145.1	54.6
64	15.0	330.0	1100.0	3.500	70.0	4.200	74.9	132.1	57.2
65	15.0	330.0	1400.0	3.730	67.0	1.390	49.9	89.8	39.9
66	15.0	330.0	1400.0	3.730	67.0	2.780	65.5	113.4	47.8
67	15.0	330.0	1400.0	3.730	67.0	4.200	74.9	130.2	55.3
68	15.0	330.0	1400.0	3.730	67.0	5.560	90.5	143.0	52.5
69	13.2	348.0	999.0	1.200	73.8	0.681	31.1	74.0	42.9
70	12.7	348.0	999.0	1.216	73.8	0.682	27.6	74.0	46.4
71	13.8	348.0	999.0	1.180	73.7	0.692	26.6	74.4	47.8
72	13.6	348.0	999.0	1.186	73.7	0.670	28.2	73.6	45.4
73	14.2	348.0	999.0	1.168	73.6	1.363	39.1	93.4	54.3
74	14.2	348.0	999.0	1.168	73.6	1.372	40.5	93.7	53.2
75	12.3	348.0	999.0	1.216	73.9	1.310	38.8	92.0	53.2
76	12.6	348.0	999.0	1.226	73.9	1.238	34.9	90.3	55.3
77	12.0	348.0	999.0	1.239	73.9	1.311	32.1	92.0	59.9
78	16.3	348.0	999.0	1.106	73.3	0.290	19.6	55.8	36.2
79	17.0	348.0	999.0	1.087	73.2	0.681	27.9	74.3	46.4
80	13.3	348.0	999.0	1.196	73.7	0.703	27.0	74.7	47.7
81	13.7	348.0	999.0	1.184	73.7	0.700	28.3	74.7	46.4
82	13.3	348.0	999.0	1.196	73.7	0.665	24.3	73.4	49.1
83	14.9	348.0	999.0	1.147	73.5	1.397	45.4	94.3	48.9
84	14.7	348.0	999.0	1.153	73.5	1.390	36.4	94.1	57.7
85	13.5	348.0	999.0	1.190	73.7	1.313	37.2	92.2	55.0
86	13.4	348.0	999.0	1.193	73.7	1.360	31.5	93.3	61.8
87	13.6	348.0	999.0	1.187	73.8	1.370	34.1	93.5	59.4
88	13.5	195.0	999.2	1.190	73.7	0.681	23.1	45.6	22.5
89	15.0	195.0	999.2	1.144	73.4	0.708	27.2	46.3	19.1
90	15.0	195.0	999.2	1.144	73.5	0.673	23.9	45.5	21.6
91	14.8	195.0	999.2	1.150	73.6	0.662	26.5	45.2	18.7
92	17.0	195.0	999.2	1.087	73.1	0.703	27.2	46.3	19.1
93	17.0	195.0	999.2	1.087	73.2	0.703	30.7	46.3	15.5
94	17.2	195.0	999.2	1.082	73.2	0.700	30.9	46.2	15.3
95	17.2	195.0	999.2	1.082	73.2	0.684	27.2	45.9	18.7

Table - 7.4.1 (contd.)

No	T	a_t	ρ_L	μ_L	σ	L	a_p exp.	a_w pred.	a_{st} obs.
	^oC	m^2/m^3	kg/m^3	mNs/m^2	mN/m	kg/m^2s	m^2/m^3		
96	17.4	195.0	999.2	1.077	73.1	0.705	27.1	46.4	19.3
97	13.7	195.0	999.2	1.184	73.7	0.713	30.5	46.3	15.8
98	13.2	195.0	999.2	1.200	73.8	0.745	24.6	47.0	22.4
99	14.2	195.0	999.2	1.168	73.6	0.703	26.1	46.1	20.0
100	14.8	195.0	999.2	1.120	73.3	1.496	41.6	59.6	18.0

Relevant details regarding Table - (7.4.1)

Data No.	System and Packing characteristics.
1-6	Absorption of Ammonia in water. Ceramic R.R., σ_c = 61 mN/m dp = 0.025 m, Ref.(13).
7-36	Absorption of CO_2 in water. Ceramic R.R., σ_c = 61 mN/m No 7-21, dp = 0.025 m, No 22-36, dp = 0.015 m, Ref.(14). (Packed depths : No.7-14 & 22-31 = 0.4m, 15-21 & 32-36 = 0.2m)
37-39	Absorption of CO_2 in methanol. Ceramic R.R., σ_c = 61 mN/m dp = 0.015 m. Ref.(14).
40-44	Absorption of CO_2 in water. Ceramic R.R., σ_c = 61 mN/m dp = 0.015 m, Ref.(15).
45-57	Absorption of CO_2 in methanol. Ceramic R.R., σ_c = 61 mN/m No. 45-52, dp = 0.015 m, No. 53-57, dp = 0.025 m, Ref.(15).
58-60	Absorption of CO_2 in aqueous methanol solutions. Methanol concentrations :- 60%, 30%, 10% ,for no.58,59,60 respectively.Ceramic R.R., σ_c= 61 mN/m. dp = 0.015 m, Ref.(15).
61-68	Absorption of CO_2 in cane sugar solutions. No.61-64, 5% No. 65-68, 10%, ceramic R.R., σ_c = 61 mN/m, dp = 0.015m Ref.(15).
69-100	Absorption of methanol vapours in water. Ceramic R.R. σ_c = 61 mN/m, No. 69-87, dp = 0.015m, 88-100, dp = 0.025 m Ref.(16,17). (Packed depth : No.69-77 & 88-93 = 0.2m, No. 78-87 & 94-100 = 0.1m).

The critical analysis of the observed values of a_{st} obtained by using approach (I) which are reported in Table (7.4.1) reveals the following :

(I) Effect of liquid flow rate (L) :-

Under otherwise identical conditions with an increase in L the values of a_{st} increase. However at high values of L, the effect of L on the values of a_{st} appears to be marginal. Thus for example for a set of observation numbers 22 to 31, under otherwise identical conditions with an increase in the value of L from 0.156 to 5.131 kg/m^2-s, the value of a_{st} increases from 35.6 m^2/m^3 to 83.4 m^2/m^3. With a further increase in L from 5.131 kg/m^2-s to 7.947 kg/m^2-s, the value of a_{st} increases marginally from 83.4 m^2/m^3 to 94.6 m^2/m^3. Also, for all the other systems/variations under consideration similar conclusion can be drawn.

(II) Effect of packing size (d_p) :-

The packing size has profound effect on the values of a_{st}. With an increase in the size of packing the values of a_{st} decrease considerably under otherwise identical conditions. Thus, for example for observation numbers (5) and (30) under otherwise identical conditions of σ_c = 61 mN/m, σ = 72.8 mN/m, μ_L = 1.008 mNs/m^2, ρ_L = 998.2 kg/m^3 and L = 5.8 to 6.1 kg/m^2-s ; with an increase in the packing size of ceramic Raschig rings from 0.015m to 0.025m the value of a_{st} decreases considerably from 94.7 m^2/m^3 to 28.1 m^2/m^3. Under otherwise identical conditions similar trend is observed for all the other systems/variations under consideration.

(III) <u>Effect of physical properties</u> μ_L, ρ_L <u>and</u> σ <u>inclusive of</u> σ_c :

Under otherwise comparable conditions with an increase in the viscosity, the value of a_{st} also decreases. Thus for example for observation numbers 74 and 61 under otherwise comparable conditions of a_t = 330 to 348 m^2/m^3, ρ_L = 999 to 1100 kg/m^3, σ = 70 to 73.6 mN/m and L = 1.372 to 1.390 kg/m^2-s, with an increase in μ_L from 1.168 to 3.50 mNs/m^2, the value of a_{st} decreases from 53.2 m^2/m^3 to 41.2 m^2/m^3. With an increase in ρ_L also, the value of a_{st} do decrease but marginally, as could be observed from sets of observations 61 to 64 and 65 to 68. Under otherwise identical conditions, it is also observed that with an increase in the value of σ, the value of a_{st} decreases as indicated by observations 51, 58, 59 and 60.

(IV) <u>Effect of packed bed height :-</u>

Packed bed height appears to have no effect on the values of a_{st}. Table (7.4.1) also gives the values of a_{st} from Cases (I) and (II).

CASE (I) : Set of observations - 68 to 93 having packed bed height 0.2 m.

CASE (II) : Set of observations - 94 to 100 having packed bed height 0.1 m.

Under otherwise comparable operating conditions, the values of a_{st} obtained for Case I & II are practically comparable indicating that the packed height appears to have no effect on the values of a_{st}.

The probable effects of different parameters on the values of

a_{st} have been already analysed in detail giving justifications in chapter (6). The observed values of a_{st} obtained under different sets of conditions do confirm all these conclusions. Thus, the static area model proposed in this investigation elucidates the different mechanisms of mass transfer during gas absorption in a packed column.

In order to correlate the data for a_{st} in terms of model parameters - system parameters and hydrodynamic parameters, one can propose the following equation :-

$$a_{st} = f(L,\ a_t^{-1},\ \rho_L^{-1},\ \mu_L^{-1},\ \sigma^{-1},\ \sigma_c) \qquad (7.13)$$

With the help of dimensional analysis, these model parameters can be grouped in terms of the following dimensionless numbers/groups :-
$Re = L/a_t\ \mu_L$, $Fr = L^2 a_t/\ \rho_L^2 g$, $We = L^2/a_t\ \rho_L \sigma$ and ratio $\sigma\ /\ \sigma_c$.
Therefore, equation (7.13) for predicting the values of a_{st} takes the following form :-

$$a_s/a_t = C\ (Re)^{\alpha}\ \ (Fr/We)^{\beta}\ \ (\sigma\ /\ \sigma_c)^{\delta} \qquad (7.14)$$

Hence, the different dimensionless groups were calculated using the data for a_{st} and the relevant corresponding physical properties of the systems reported in Table - (7.4.1). These dimensionless numbers/parameters required for the processing of the data for a_{st} are reported in Table (7.4.2).

7.4.3 Statistical analysis for different correlations :

Basis : Approach (I) Using equation (7.11) :

Processing of the data reported in Table (7.4.2) was done by two methodologies namely (1) DSC - Powell algorithm (2)

Table - (7.4.2)

Results inclusive of processing parameters for a_{st} based on $(a_p/a_t)_{exp}$

Based on Equation (7.11) : $a_{st}/a_t = (a_w/a_t)_{pred} - (a_p/a_t)_{exp}$

No.	L kg/m^2s	a_w/a_t pred.	a_p/a_t exp.	Re	Fr/We	σ/σ_c	a_{st}/a_t obs.	a_{st}/a_t pred.	% err
1	0.678	0.235	0.144	3.450	0.283	1.193	0.091	0.093	-1.96
2	1.350	0.297	0.203	6.868	0.283	1.193	0.094	0.105	-11.99
3	2.034	0.340	0.247	10.350	0.283	1.193	0.093	0.112	-20.86
4	5.400	0.472	0.351	27.473	0.283	1.193	0.121	0.133	-9.58
5	6.103	0.492	0.348	31.049	0.283	1.193	0.144	0.136	5.76
6	6.800	0.510	0.400	34.595	0.283	1.193	0.110	0.138	-25.70
7	0.111	0.128	0.062	0.562	0.283	1.193	0.066	0.068	-3.42
8	0.204	0.157	0.060	1.039	0.283	1.193	0.098	0.076	22.64
9	0.312	0.181	0.074	1.585	0.283	1.193	0.107	0.081	23.97
10	0.440	0.204	0.108	2.239	0.283	1.193	0.096	0.086	10.10
11	0.622	0.229	0.099	3.163	0.283	1.193	0.129	0.092	29.08
12	1.392	0.300	0.158	7.081	0.283	1.193	0.142	0.105	25.67
13	4.716	0.451	0.268	23.992	0.283	1.193	0.184	0.130	29.20
14	7.947	0.538	0.369	40.432	0.283	1.193	0.168	0.142	15.41
15	0.146	0.141	0.082	0.741	0.283	1.193	0.058	0.071	-22.34
16	0.358	0.190	0.101	1.820	0.283	1.193	0.089	0.083	6.13
17	0.598	0.226	0.137	3.043	0.283	1.193	0.089	0.091	-2.09
18	1.240	0.288	0.172	6.311	0.283	1.193	0.116	0.103	11.31
19	2.043	0.341	0.233	10.393	0.283	1.193	0.108	0.113	-4.35
20	3.116	0.393	0.293	15.851	0.283	1.193	0.099	0.121	-22.02
21	6.265	0.496	0.364	31.871	0.283	1.193	0.133	0.137	-2.97
22	0.156	0.131	0.028	0.445	0.901	1.193	0.102	0.117	-13.83
23	0.302	0.163	0.043	0.861	0.901	1.193	0.120	0.131	-8.67
24	0.585	0.204	0.064	1.667	0.901	1.193	0.139	0.146	-4.97
25	0.725	0.219	0.093	2.066	0.901	1.193	0.125	0.152	-21.17
26	0.927	0.238	0.087	2.641	0.901	1.193	0.151	0.159	-4.92
27	1.514	0.280	0.087	4.317	0.901	1.193	0.194	0.173	10.90
28	3.188	0.360	0.156	9.089	0.901	1.193	0.203	0.196	3.52
29	5.131	0.422	0.182	14.628	0.901	1.193	0.240	0.213	11.11
30	5.846	0.441	0.169	16.667	0.901	1.193	0.272	0.218	19.91
31	7.947	0.489	0.217	22.655	0.901	1.193	0.272	0.230	15.46
32	0.203	0.143	0.040	0.578	0.901	1.193	0.103	0.122	-18.65
33	0.529	0.197	0.080	1.508	0.901	1.193	0.117	0.144	-22.61
34	0.845	0.230	0.093	2.409	0.901	1.193	0.138	0.156	-13.33
35	2.043	0.310	0.126	5.823	0.901	1.193	0.184	0.182	1.07
36	4.235	0.396	0.185	12.074	0.901	1.193	0.211	0.206	2.12
37	0.290	0.337	0.050	1.244	0.357	0.377	0.286	0.202	29.47
38	0.409	0.378	0.108	1.757	0.357	0.377	0.270	0.214	20.51
39	0.539	0.415	0.117	2.316	0.357	0.377	0.298	0.225	24.49
40	0.280	0.159	0.066	0.742	0.818	1.205	0.093	0.120	-29.08
41	0.550	0.200	0.090	1.457	0.818	1.205	0.110	0.135	-22.80
42	2.220	0.319	0.178	5.880	0.818	1.205	0.142	0.172	-21.55
43	2.780	0.344	0.194	7.364	0.818	1.205	0.151	0.179	-18.86
44	5.500	0.433	0.265	14.569	0.818	1.205	0.168	0.201	-19.69
45	0.280	0.347	0.165	1.622	0.309	0.359	0.181	0.204	-12.54
46	0.550	0.435	0.199	3.187	0.309	0.359	0.236	0.229	2.99
47	0.830	0.499	0.217	4.809	0.309	0.359	0.281	0.246	12.66
48	1.120	0.552	0.284	6.489	0.309	0.359	0.268	0.259	3.41

Table - 7.4.2 (contd.)

No.	L kg/m^2s	a_w/a_t pred.	a_p/a_t exp.	Re	Fr/We	σ/σ_c	a_{st}/a_t obs.	a_{st}/a_t pred.	% err
49	1.670	0.631	0.331	9.676	0.309	0.359	0.300	0.277	7.50
50	2.220	0.694	0.378	12.863	0.309	0.359	0.316	0.291	7.74
51	2.780	0.748	0.397	16.108	0.309	0.359	0.351	0.303	13.78
52	5.500	0.941	0.572	31.867	0.309	0.359	0.369	0.341	7.61
53	0.550	0.469	0.310	5.080	0.122	0.359	0.159	0.156	2.24
54	0.830	0.539	0.400	7.667	0.122	0.359	0.139	0.167	-20.51
55	1.120	0.596	0.430	10.345	0.122	0.359	0.166	0.176	-6.26
56	1.670	0.681	0.510	15.426	0.122	0.359	0.171	0.189	-10.34
57	2.220	0.749	0.600	20.506	0.122	0.359	0.149	0.198	-32.68
58	2.780	0.604	0.331	5.903	0.373	0.492	0.273	0.223	18.53
59	2.780	0.502	0.274	5.265	0.466	0.656	0.228	0.198	12.95
60	2.780	0.412	0.236	7.109	0.623	0.902	0.176	0.192	-9.15
61	1.390	0.276	0.151	1.203	0.707	1.148	0.125	0.126	-0.98
62	2.780	0.348	0.199	2.407	0.707	1.148	0.150	0.142	5.17
63	5.560	0.440	0.274	4.814	0.707	1.148	0.165	0.160	3.17
64	4.200	0.400	0.227	3.636	0.707	1.148	0.173	0.153	11.90
65	1.390	0.272	0.151	1.129	0.532	1.098	0.121	0.112	7.70
66	2.780	0.344	0.199	2.259	0.532	1.098	0.145	0.126	13.18
67	4.200	0.394	0.227	3.412	0.532	1.098	0.168	0.135	19.36
68	5.560	0.433	0.274	4.517	0.532	1.098	0.159	0.142	10.92
69	0.681	0.213	0.089	1.630	0.912	1.209	0.123	0.145	-17.96
70	0.682	0.213	0.079	1.612	0.913	1.210	0.133	0.145	-8.85
71	0.692	0.214	0.076	1.684	0.911	1.208	0.137	0.146	-6.38
72	0.670	0.211	0.081	1.623	0.912	1.208	0.131	0.145	-11.30
73	1.363	0.269	0.112	3.353	0.911	1.207	0.156	0.165	-5.46
74	1.372	0.269	0.116	3.377	0.911	1.207	0.153	0.165	-7.90
75	1.310	0.264	0.111	3.096	0.914	1.211	0.153	0.162	-6.10
76	1.238	0.259	0.100	2.902	0.914	1.211	0.159	0.161	-0.92
77	1.311	0.264	0.092	3.041	0.915	1.212	0.172	0.162	5.95
78	0.290	0.160	0.056	0.754	0.907	1.202	0.104	0.127	-22.63
79	0.681	0.214	0.080	1.800	0.905	1.200	0.133	0.148	-11.07
80	0.703	0.215	0.078	1.688	0.912	1.209	0.137	0.146	-6.68
81	0.700	0.215	0.081	1.698	0.912	1.208	0.133	0.146	-9.92
82	0.665	0.211	0.070	1.597	0.912	1.209	0.141	0.145	-2.72
83	1.397	0.271	0.131	3.500	0.909	1.205	0.140	0.166	-18.16
84	1.390	0.270	0.105	3.464	0.910	1.206	0.166	0.166	0.00
85	1.313	0.265	0.107	3.170	0.912	1.208	0.158	0.163	-3.20
86	1.360	0.268	0.090	3.277	0.912	1.208	0.178	0.164	7.72
87	1.370	0.269	0.098	3.316	0.912	1.209	0.171	0.164	3.80
88	0.681	0.234	0.118	2.934	0.286	1.208	0.115	0.090	21.89
89	0.708	0.237	0.140	3.173	0.285	1.203	0.098	0.091	6.59
90	0.673	0.233	0.122	3.015	0.285	1.205	0.111	0.091	18.25
91	0.662	0.232	0.136	2.951	0.286	1.207	0.096	0.090	5.84
92	0.703	0.238	0.139	3.314	0.284	1.198	0.098	0.092	5.94
93	0.703	0.237	0.158	3.314	0.284	1.200	0.080	0.092	-15.76
94	0.700	0.237	0.158	3.317	0.284	1.199	0.079	0.092	-17.28
95	0.684	0.235	0.139	3.240	0.284	1.199	0.096	0.092	4.30
96	0.705	0.238	0.139	3.358	0.284	1.199	0.099	0.092	6.68
97	0.713	0.238	0.156	3.090	0.286	1.208	0.081	0.091	-12.18
98	0.745	0.241	0.126	3.182	0.286	1.209	0.115	0.091	20.33
99	0.703	0.236	0.134	3.084	0.286	1.207	0.102	0.091	11.22
100	1.496	0.306	0.213	6.849	0.285	1.202	0.092	0.104	-13.10

Optimization by modifed simplex algorithm of Nelder and Mead. The results obtained using these two methodologies are reported in Table (7.4.3) and are discussed herewith.

CASE (I) : Initially the plausible values of indices α β δ and proportionality constant C were obtained by performing graphical analysis. The different plots of a_{st} Vs Re or (Fr/We) or (σ / σ_c) etc were obtained (not shown herewith) and the following approximate values of indices were estimated :-

α = 0.172, β = 0.33, δ = -0.666 and C = 0.1659.

The statistical analysis of data fit based on the graphical estimate [step (1)] was as under :-

% E_{avg} = -17.7, % E_{abs} = 20.2 and % S_{dev} = 2.67.

CASE (II) : Using the graphically obtained values of indices as the satisfactory guesses, the DSC - Powell algorithm was utilised to obtain the optimum values of indices. The regression of data as per step (2) yielded the following correlation :-

$$a_s/a_t = 0.1659\ (Re)^{0.0758}\ (Fr/We)^{0.3372}\ (\sigma / \sigma_c)^{-0.6728} \quad (7.15)$$

By changing the direction of search sequences, it was observed that a correlation with superior statistical analysis could be obtained. The direction of search sequence in the step (2) was as under :-

Re ---> Fr/We ---> (σ/ σ_c) ---> C

and that in step (5) was

(σ/ σ_c) ---> Fr/We ---> Re ---> C.

Table - (7.4.3)

Statistical analysis for different correlations of a_{st} based on $(a_p / a_t)_{exp}$

Equation 7.11 : $a_{st} / a_t = (a_w / a_t)_{pred} - (a_p / a_t)_{exp}$

Correlation Structure : $a_{st} / a_t = C \cdot Re^{\alpha} \cdot (Fr/We)^{\beta} \cdot (\sigma / \sigma_c)^{\delta}$.

No.	C	α	β	δ	% E_{avg}	% E_{abs}	% S_{dev}

Case 1 :- Graphical estimation of data indicated the plausible values of indices α, β, δ and C were 0.172, 0.333, -0.666, and 0.1659 respectively. The Statistics of fit is indicated below.

1	0.1659	0.1722	0.333	-0.666	-17.7	20.2	2.674.

Case 2 :- Optimisation by the D.S.C. - Powell algorithm.

Initialisation were based on guesses of indices, α, β, δ, and C obtained as 0.172, 0.333, -0.666, 0.1659 respectively from graphical estimation of the data. Direction of search sequence α, β, δ, C. respectively.

2	0.1659	0.0758	0.3372	-0.6728	-3.26	15.18	3.05.

Direction of search sequence changed to β, α, δ, C. Initialisation as in step no 2.

3	0.1659	0.17	0.5047	-0.665	-2.95	13.45	2.64.

Direction of search sequence changed to C, δ, β, α,. Initialisation as in step no 2.

4	0.1423	0.17	0.3327	-0.737	-1.12	13.27	2.79

Direction of search sequence changed to δ, β, α, C. Initialisation as in step no. 2.

5*	0.1605	0.1726	0.50	-0.725	-0.40	12.34	2.42

Value of the index δ fixed as -0.442 similar to the correlations for wetted surface area and effective interfacial area during physical absorption . Direction of search sequence changed to α, β, C. Initialisation as in step no. 2.

6	0.1397	0.0220	0.3796	-0.442	1.98	14.37	3.51.

Table - 7.4.3 (contd.)

No.	C	α	β	δ	% E_{avg}	% E_{abs}	% S_{dev}
Value of index α fixed as 0.099 similar to the correlation for effective interfacial area during physical absorption . Direction of search sequence changed to β, δ C. Initialisation as in step no. 2.							
7	0.1699	0.099	0.385	-0.653	-4.99	15.09	2.87.
Value of index α fixed as 0.0014 similar to the correlation for wetted surface area. Direction of search sequence changed to β, δ, C. Initialisation as in step no. 2.							
8	0.1868	0.0014	0.3937	-0.849	1.998	17.09	3.56.
Case 3 : - Optimisation by the Modified Simplex algorithm of Nelder and Mead							
All parameters are iterated, base values as obtained from step no 2. Each indice value perturbed 50 % at a time.							
9	0.1575	0.164	0.482	-0.822	0.89	11.97	2.34.
β value fixed as 0.50. Other parameters iterated as in step no. 9.							
10	0.150	0.208	0.50	-0.767	0.69	11.77	2.34.
Value of index δ fixed as -0.442 similar to the wetted surface area correlations. Other parameters iterated as in step no. 9.							
11	0.36	0.220	0.407	-0.442	0.10	13.93	3.50.

Note : The values of indices in the finalised generalised correlation are as per regression step marked by (*)

When the regression was done as per step (5), the mathematical modelling of the data yielded the following correlations :-

$$(a_s/a_t) = 0.1605\ (Re)^{0.1726}\ (Fr/We)^{0.5}\ (\sigma/\sigma_c)^{-0.725} \quad (7.16)$$

The statistical analysis for both the correlations [Equations (7.15)and (7.16)] was as under :-.

The values of % E_{abs}, % E_{avg} and S_{dev} for the correlation (7.15) were 15.18, -3.26 and 3.05 respectively, while those for the correlation (7.16) were 12.34 , -0.40, and 2.42 respectively. Thus by changing the direction of search sequence one can decrease the values of % E_{abs}, % E_{avg} and % S_{dev} to some extent. Therefore it can be concluded that one has to be careful in selecting a suitable methodology while performing mathematical modelling of data.

Further, by prefixing the indices of some groups as done in steps (6) to (8) yielded different correlations. The statistical analysis of these correlations was relatively inferior as compared to step (5). Therefore, the indices of all the numbers in equation (7.16) inclusive of the value of proportionality constant are such that the correlation under consideration predicts the values of a_{st} with the least amount of error.

CASE (III) : Using the optimization technique : Modifed simplex algorithm of Nelder and Mead and by prefixing the indices of different numbers did nor alter the statistical analysis appreciably for regression steps (9) to (11) wherein the values of % E_{avg}, % E_{abs} and % S_{dev} remained in the ranges of (0.10 to 0.89), (11.72 to 13.93) and (2.3 to 3.5) respectively.

When the index of (σ / σ_c) group was fixed to the value of -0.442 [similar to the index of (σ / σ_c) group obtained for the correlations of (a_w/a_t) and (a_p/a_t)] and the regression of data was performed as per step (11). It resulted in the undermentioned correlation :-

$$(a_{st}/a_t) = 0.36\ (Re)^{0.22}\ (Fr/We)^{0.407}\ (\sigma / \sigma_c)^{-0.442} \qquad (7.17)$$

The values of % E_{avg}, % E_{abs} and % S_{dev} were 0.1, 13.93, and 3.5 respectively. The data fit of (a_{st}/a_t) by equation (7.17) is expected to be to some extent inferior than the data fit of (a_{st}/a_t) by equation (7.16). However, this correlation [Equation (7.17)] could also be considered as a satisfactory correlation for predicting the values of (a_{st}/a_t). It is interesting to observe that the index of (σ / σ_c) in equations (7.3), (7.7) and (7.17) is the same and the value is -0.442.

7.4.4 Results for a_{st} by approach (II) : Use of equation (7.12) :-

The generalised correlation developed in this investigation for (a_p/a_t) [Equation (7.7)] could also be utilised conveniently to obtain the values of a_p under otherwise identical conditions mentioned for the data bank of experimental values of a_w. The data bank of a_w and the relevant conditions mentioned therein in Table (5.1) were utilised to obtain the predicted values of (a_p) under otherwise identical conditions. The values of a_{st} were estimated accordingly by using equation (7.12). The observed value of a_{st} obtained by using the appraoch (II) are reported in Table (7.4.4) which consists of 100 data points covering 21 systems/variations.

The critical analysis of these results indicate the following:-

(i) With an increase in L, the values of a_{st} increase.

(ii) With an increase in ρ_L, μ_L and σ / σ_c the values of a_{st} decrease.

(iii) With an increase in the packing size, the values of a_{st} decrease considerably.

The parametric dependencies of different variables and their effect on the values of a_{st} observed for approach (II) and that observed for approach (I) are thus identical.

In order to correlate the observed values of a_{st} by approach (II), the equation (7.14) was utilised. The different dimensionless groups required for the processing of the data for a_{st} by equation (7.14) are reported in Table (7.4.4).

7.4.5 Statistical analysis of different correlations :

Basis - Approach (II) Using equation (7.12) :

Processing of the data reported in Table - (7.4.4) was also done by the same methodologies which were utilised while processing the data of a_{st} obtained by using approach (I) : Use of equation (7.11). The results obtained using these methodologies are reported in Table (7.4.5) and are discussed herewith.

It was observed that by using the DSC-Powell algorithm, and by performing regressions as per steps (2) to (4), by changing the direction of search sequence, altered the values of % E_{abs}, % E_{avg} and % S_{dev} considerably.

Table - (7.4.4)

Results inclusive of processing parameters for a_{st} based on $(a_w/a_t)_{exp}$.

Based on Equation (7.12) : $a_{st}/a_t = (a_w/a_t)_{exp} - (a_p/a_t)_{pred}$

No.	L kg/m^2s	a_w/a_t exp.	a_p/a_t pred.	Re	Fr/We	σ/σ_c	a_{st}/a_t obs.	a_{st}/a_t pred.	% err
1	6.781	0.460	0.369	40.477	0.219	1.510	0.091	0.130	-42.92
2	12.206	0.470	0.509	72.859	0.219	1.510	-0.039	0.136	446.38
3	13.562	0.642	0.539	80.954	0.219	1.510	0.103	0.137	-33.08
4	1.356	0.279	0.120	3.763	1.015	1.510	0.159	0.136	14.67
5	3.390	0.367	0.198	9.407	1.015	1.510	0.169	0.145	14.13
6	6.781	0.451	0.289	18.816	1.015	1.510	0.162	0.153	5.66
7	1.356	0.320	0.174	12.106	0.098	1.510	0.146	0.106	27.45
8	3.390	0.400	0.287	30.265	0.098	1.510	0.113	0.113	-0.48
9	6.781	0.500	0.420	60.539	0.098	1.510	0.080	0.119	-48.49
10	13.562	0.560	0.613	121.078	0.098	1.510	-0.053	0.125	335.55
11	4.230	0.445	0.271	12.788	1.009	1.000	0.174	0.182	-4.41
12	5.830	0.509	0.323	17.625	1.009	1.000	0.186	0.186	0.00
13	10.850	0.685	0.453	32.801	1.009	1.000	0.232	0.195	15.87
14	13.080	0.720	0.502	39.543	1.009	1.000	0.218	0.198	9.31
15	5.400	0.500	0.295	14.362	1.584	0.972	0.205	0.198	2.99
16	8.100	0.600	0.369	21.543	1.584	0.972	0.231	0.204	11.58
17	0.850	0.240	0.121	1.641	0.839	0.833	0.119	0.167	-40.69
18	3.400	0.396	0.259	6.564	0.839	0.833	0.137	0.185	-35.04
19	5.100	0.455	0.324	9.846	0.839	0.833	0.131	0.190	-44.83
20	6.800	0.500	0.379	13.127	0.839	0.833	0.121	0.194	-60.32
21	0.500	0.279	0.111	1.795	0.243	0.833	0.168	0.141	16.45
22	1.190	0.342	0.178	4.271	0.243	0.833	0.164	0.150	8.67
23	2.270	0.441	0.253	8.148	0.243	0.833	0.188	0.157	16.28
24	7.200	0.602	0.476	25.844	0.243	0.833	0.126	0.171	-36.10
25	0.140	0.210	0.072	0.475	0.379	0.472	0.138	0.180	-30.03
26	0.280	0.280	0.105	0.949	0.379	0.472	0.175	0.189	-7.97
27	0.550	0.350	0.151	1.864	0.379	0.472	0.199	0.199	0.00
28	1.110	0.410	0.222	3.762	0.379	0.472	0.188	0.209	-11.62
29	1.380	0.450	0.250	4.678	0.379	0.472	0.200	0.213	-6.66
30	2.780	0.600	0.367	9.423	0.379	0.472	0.233	0.224	3.67
31	0.278	0.187	0.081	1.637	0.240	0.903	0.106	0.134	-26.25
32	0.550	0.217	0.117	3.238	0.240	0.903	0.100	0.141	-41.51
33	1.110	0.290	0.172	6.535	0.240	0.903	0.118	0.148	-26.17
34	2.780	0.375	0.285	16.366	0.240	0.903	0.090	0.159	-76.13
35	5.500	0.490	0.414	32.380	0.240	0.903	0.076	0.167	-118.92
36	0.140	0.180	0.059	0.824	0.222	0.833	0.121	0.131	-7.95
37	0.278	0.200	0.085	1.637	0.222	0.833	0.115	0.138	-20.13
38	0.550	0.250	0.124	3.238	0.222	0.833	0.126	0.145	-14.86
39	1.110	0.300	0.182	6.535	0.222	0.833	0.118	0.153	-29.12
40	1.380	0.350	0.205	8.124	0.222	0.833	0.145	0.155	-6.79
41	2.780	0.420	0.300	16.366	0.222	0.833	0.120	0.163	-36.52
42	0.140	0.200	0.066	0.824	0.185	0.694	0.134	0.140	-4.37
43	0.278	0.250	0.096	1.637	0.185	0.694	0.154	0.147	4.44
44	0.550	0.310	0.140	3.238	0.185	0.694	0.170	0.154	9.25
45	1.110	0.380	0.205	6.535	0.185	0.694	0.175	0.163	6.93
46	1.380	0.400	0.231	8.124	0.185	0.694	0.169	0.165	2.10
47	2.780	0.520	0.339	16.366	0.185	0.694	0.181	0.174	3.81
48	0.140	0.230	0.079	0.824	0.140	0.528	0.151	0.154	-2.11
49	0.278	0.300	0.115	1.637	0.140	0.528	0.185	0.162	12.33

Table - 7.4.4 (contd.)

No.	L kg/m^2s	a_w/a_t exp.	a_p/a_t pred.	Re	Fr/We	σ/σ_c	a_{st}/a_t obs.	a_{st}/a_t pred.	% err
50	0.550	0.380	0.168	3.238	0.140	0.528	0.212	0.170	19.88
51	1.110	0.480	0.246	6.535	0.140	0.528	0.234	0.179	23.39
52	1.380	0.520	0.277	8.124	0.140	0.528	0.243	0.182	24.99
53	2.780	0.620	0.407	16.366	0.140	0.528	0.213	0.192	10.11
54	0.140	0.150	0.053	0.439	0.211	0.861	0.097	0.122	-25.94
55	0.280	0.180	0.077	0.877	0.211	0.861	0.103	0.129	-25.27
56	0.550	0.268	0.112	1.723	0.211	0.861	0.156	0.135	13.44
57	1.400	0.300	0.186	4.386	0.211	0.861	0.114	0.145	-27.45
58	2.780	0.400	0.271	8.709	0.211	0.861	0.129	0.152	-18.27
59	4.150	0.448	0.338	13.001	0.211	0.861	0.110	0.157	-42.19
60	0.140	0.160	0.046	0.194	0.213	0.917	0.114	0.112	1.71
61	0.280	0.185	0.068	0.388	0.213	0.917	0.117	0.118	-0.17
62	0.560	0.275	0.099	0.776	0.213	0.917	0.176	0.124	29.78
63	1.400	0.310	0.163	1.939	0.213	0.917	0.147	0.132	9.98
64	1.670	0.345	0.179	2.313	0.213	0.917	0.166	0.134	19.00
65	2.100	0.380	0.203	2.909	0.213	0.917	0.177	0.136	22.77
66	2.780	0.410	0.237	3.850	0.213	0.917	0.173	0.139	19.47
67	4.150	0.450	0.295	5.748	0.213	0.917	0.155	0.143	7.37
68	0.140	0.200	0.055	0.279	0.093	0.833	0.145	0.107	26.19
69	0.280	0.250	0.081	0.558	0.093	0.833	0.169	0.112	33.59
70	1.400	0.400	0.195	2.791	0.093	0.833	0.205	0.127	38.40
71	2.780	0.410	0.283	5.542	0.093	0.833	0.127	0.133	-4.91
72	0.560	0.195	0.074	0.862	2.344	1.098	0.121	0.161	-32.69
73	1.160	0.265	0.110	1.786	2.344	1.098	0.155	0.170	-9.40
74	1.680	0.300	0.135	2.587	2.344	1.098	0.165	0.174	-5.41
75	2.240	0.324	0.158	3.450	2.344	1.098	0.166	0.178	-6.98
76	2.780	0.343	0.177	4.281	2.344	1.098	0.166	0.181	-9.19
77	0.560	0.234	0.096	0.948	1.610	0.754	0.138	0.185	-33.53
78	1.160	0.310	0.142	1.963	1.610	0.754	0.168	0.195	-16.32
79	1.680	0.350	0.174	2.843	1.610	0.754	0.176	0.200	-14.08
80	2.780	0.453	0.230	4.705	1.610	0.754	0.223	0.208	6.90
81	0.560	0.290	0.091	0.472	1.620	0.738	0.199	0.178	10.69
82	1.160	0.345	0.136	0.977	1.620	0.738	0.209	0.187	10.46
83	1.680	0.395	0.166	1.415	1.620	0.738	0.229	0.192	15.84
84	2.240	0.428	0.195	1.886	1.620	0.738	0.233	0.197	15.76
85	2.780	0.452	0.219	2.341	1.620	0.738	0.233	0.200	14.27
86	0.560	0.180	0.062	0.383	2.448	1.230	0.118	0.144	-22.40
87	1.160	0.240	0.093	0.793	2.448	1.230	0.147	0.152	-3.22
88	1.680	0.278	0.114	1.149	2.448	1.230	0.164	0.156	5.01
89	2.240	0.320	0.133	1.532	2.448	1.230	0.187	0.160	14.73
90	2.780	0.318	0.150	1.901	2.448	1.230	0.168	0.162	3.77
91	0.560	0.165	0.053	0.089	2.277	1.230	0.112	0.128	-14.38
92	1.160	0.195	0.079	0.184	2.277	1.230	0.116	0.135	-16.42
93	1.680	0.245	0.097	0.266	2.277	1.230	0.148	0.139	6.40
94	2.240	0.270	0.113	0.355	2.277	1.230	0.157	0.142	9.60
95	2.780	0.285	0.127	0.440	2.277	1.230	0.158	0.144	8.63
96	0.560	0.170	0.058	0.255	2.328	1.246	0.112	0.138	-23.69
97	1.160	0.230	0.087	0.529	2.328	1.246	0.143	0.146	-1.82
98	1.680	0.260	0.107	0.766	2.328	1.246	0.153	0.150	2.51
99	2.240	0.280	0.125	1.021	2.328	1.246	0.155	0.153	1.61
100	2.780	0.300	0.140	1.267	2.328	1.246	0.160	0.155	2.77

Table (7.4.5)

Statistical analysis for different correlations of a_{st} based on $(a_w / a_t)_{exp}$

Equation 7.12 : $a_{st} / a_t = (a_w / a_t)_{exp} - (a_p / a_t)_{pred}$

Correlation Structure : $a_{st} / a_t = C \cdot Re^{\alpha} \cdot (Fr/We)^{\beta} \cdot (\sigma / \sigma_c)^{\delta}$.

No.	C	α	β	δ	% E_{avg}	% E_{abs}	% S_{dev}

Case 1 :- Optimisation by the D.S.C. - Powell algorithm.

Initialisation were based on guesses of indices, α, β, δ, and C obtained as 0.172, 0.333, -0.666, 0.1659 respectively from graphical estimation of the data. Direction of search sequence α, β, δ, C. respectively.

1	0.17	0.02	0.3395	-0.6678	-2.60	25.9	4.82.

Direction of search sequence changed to β, α, δ, C. Initialisation as in step no 1

2	0.1507	0.0734	0.143	-0.4937	-5.5	17.82	3.16.

Direction of search sequence changed to C, δ, β, α,. Initialisation as in step no 1

3	0.1522	0.17	0.497	-0.7158	-0.90	33.87	6.34.

Direction of search sequence changed to δ, β,$\cdot$ α, C. Initialisation as in step no. 1

4	0.1284	0.2338	0.28	-0.0043	-6.20	32.45	5.77.

Case 2 : - Optimisation by the Modified Simplex algorithm of Nelder and Mead

All parameters are iterated, base values as obtained from step no 1. Each index value perturbed 50 % at a time.

5	0.1519	0.07	0.1458	-0.564	-6.27	18.4	3.15.

Note : Data points 2 and 10 of Table (7.4.4) wherein the values of $(a_p)_{pred} > (a_w)_{exp}$ were excluded from statistical analysis hence the values of various errors listed here are for 98 data points.

The direction of search sequence in step (2) was as under :-

$(Fr/We) \longrightarrow (Re) \longrightarrow (\sigma / \sigma_c) \longrightarrow C$

When the regression was done as per step (2), the mathematical modelling of the data yielded the following correlation having statistical analysis as % E_{abs} = 17.82, % E_{avg} = -5.5 and % S_{dev} = 3.16 :-

$$(a_s/a_t) = 0.1507\ (Re)^{0.07}\ (Fr/Wr)^{0.143}\ (\sigma / \sigma_c)^{-0.49} \qquad (7.18)$$

The direction of search sequence in step (4) was as under :-

$(\sigma / \sigma_c) \longrightarrow (Fr/We) \longrightarrow Re \longrightarrow C.$

When regression was done as per step (4), the mathematical modelling of the data yielded the following correlation having statistical analysis as % E_{abs} = 32.45, % E_{avg} = - 6.2 and % S_{dev} = 5.57 :-

$$(a_{st}/a_t) = 0.1284\ (Re)^{0.2338}\ (Fr/We)^{0.28}\ (\sigma / \sigma_c)^{-0.0043} \qquad (7.19)$$

The data fit of (a_{st}/a_t) by equation (7.19) is expected to be highly unsatisfactory as could be observed from the satisfical analysis.

Thus, sometimes misleading results can be obtained. Inconsistent results are also likely to be obtained. Also the correlations with highly inferior statistical analysis are likely to be developed. Hence one must be very careful while using different optimization techniques for obtaining generalised correlations by mathematical modelling.

Using optimization technique the modified simplex algorithm of Nelder and Mead,by performing regression of the data as per step (5), yielded the following correlation having statistical analysis as % E_{avg} = 18.4, % E_{avg} = -6.27, and % S_{dev} = 3.15 :-

$$(a_{st}/a_t) = 0.1519\ (Re)^{0.07}\ (Fr/We)^{0.1458}\ (\sigma / \sigma_c)^{-0.564} \qquad (7.20)$$

The statistical analysis of the correlations [equations (7.18) and (7.20)] is comparable. Hence both the correlations can be used satisfactorily for predicting the values of (a_{st}) by approach (II).

7.4.6 Comparison of Correlations for predicting the values of a_{st} by approaches (I) and (II) :

The values of (a_{st}/a_t) can be predicted satisfactorily by the correlation [Equation (7.16)] using approach (I). The detailed statistical analysis of the correlation [Equation (7.16)] can be described as follows :-

(i) The values of % E_{abs}, % E_{avg} and % S_{dev} were 12.34, 0.4 and 2.42 respectively.

(ii) From the 100 data points, 75 % of the predicted values of a_{st} were within ± 25 % of the observed data values, 63 % within ± 15 % and 40 % within ± 10 %.

Thus, while obtaining a generalised correlation for predicting the values of a_{st} by mathematical modelling, the following two approaches have been used :

(i) Approach (I) based on equation (7.11).

(ii) Approach (II) based on equation (7.12).

The methodology used in approach (I) has yielded the correlation : Equation (7.16) Further the methodology used in approach (II) has yielded the correlation : Equation (7.18). The comparison of the satistical analysis of the correlations indicates that the equation (7.16) for predicting the values of a_{st}(% E_{abs} = 12.34) appears to be more reliable and appropriate than the equation (7.18) for predicting the values of a_{st} (% E_{av} = 17.82). Therefore, the basis used for predicting the values of a_{st} in approach (I) also appears to be more reliable and appropriate than that used in approach (II).

7.4.7 Comparison between observed values and predicted values of a_{st} :

The observed values of (a_{st}/a_t) obtained by using data bank of a_p by approach (I) and the predicted value of (a_{st}/a_t) obtained by correlation [Equation (7.16)] are tabulated in Table (7.4.6) and are plotted in Figure (7.4).

Thus, figure (7.4) shows a parity plot of equation (7.16) wherein the values of (a_{st}/a_t) predicted have been plotted versus (a_{st}/a_t) observed values. The satisfactory correlation fit in Figure (7.4) clearly reflects that equation (7.16) can correlate satisfactorily all the data on a_{st}.

The generalised correlation proposed by Puranik and Vogelpohl (106) [Equation (2.11)] happens to be the only correlation available

Table (7.4.6)

Comparison between observed and predicted values of a_{st} based on (a_p /a_t)$_{expt.}$

No.	a_w pred.	a_p (m^2/m^3) exp.	a_{st} obs.	a_{st}/a_t obs.	a_{st}/a_t pred. This work	% err	a_{st}/a_t pred. Puranik & Vogelpohl	% err
1	45.9	28.1	17.8	0.091	0.093	-1.96	0.114	-25.02
2	57.8	39.6	18.2	0.094	0.105	-11.99	0.114	-21.93
3	66.4	48.2	18.1	0.093	0.112	-20.86	0.114	-22.61
4	92.1	68.4	23.7	0.121	0.133	-9.58	0.114	6.07
5	95.9	67.8	28.1	0.144	0.136	5.76	0.114	20.91
6	99.5	78.0	21.5	0.110	0.138	-25.70	0.114	-3.54
7	25.0	12.2	12.8	0.066	0.068	-3.42	0.114	-73.44
8	30.7	11.6	19.1	0.098	0.076	22.64	0.114	-16.69
9	35.4	14.5	20.9	0.107	0.081	23.97	0.114	-6.62
10	39.7	21.0	18.7	0.096	0.086	10.10	0.114	-18.78
11	44.6	19.4	25.2	0.129	0.092	29.08	0.114	11.72
12	58.4	30.8	27.6	0.142	0.105	25.67	0.114	19.50
13	88.0	52.2	35.8	0.184	0.130	29.20	0.114	37.88
14	104.4	72.0	32.3	0.167	0.142	15.03	0.113	32.14
15	27.3	16.0	11.3	0.058	0.071	-22.46	0.113	-95.03
16	36.9	19.7	17.1	0.088	0.083	6.15	0.113	-28.00
17	44.0	26.6	17.4	0.089	0.091	-2.09	0.114	-27.92
18	56.2	33.5	22.7	0.116	0.103	11.31	0.114	2.01
19	66.5	45.4	21.0	0.108	0.113	-4.35	0.114	-5.78
20	76.6	57.2	19.3	0.099	0.121	-22.02	0.114	-15.00
21	96.8	70.9	25.9	0.133	0.137	-2.97	0.114	13.98
22	45.5	9.9	35.6	0.102	0.117	-13.83	0.219	-114.31
23	56.8	15.0	41.8	0.120	0.131	-8.67	0.219	-82.56
24	70.9	22.3	48.5	0.139	0.146	-4.97	0.219	-57.36
25	76.2	32.5	43.6	0.125	0.152	-21.17	0.219	-75.02
26	82.7	30.1	52.6	0.151	0.159	-4.92	0.219	-45.26
27	97.5	30.1	67.4	0.194	0.173	10.90	0.219	-13.33
28	125.2	54.4	70.8	0.203	0.196	3.52	0.219	-7.92
29	146.9	63.5	83.4	0.240	0.213	11.11	0.219	8.41
30	153.4	58.8	94.7	0.272	0.218	19.91	0.219	19.31
31	170.1	75.5	94.6	0.272	0.230	15.46	0.219	19.23
32	49.7	13.9	35.8	0.103	0.122	-18.65	0.219	-113.54
33	68.5	27.7	40.8	0.117	0.144	-22.61	0.219	-86.99
34	80.2	32.3	47.9	0.138	0.156	-13.33	0.219	-59.42
35	107.8	43.9	63.9	0.184	0.182	1.07	0.219	-19.50
36	137.7	64.4	73.3	0.211	0.206	2.12	0.219	-4.25
37	117.1	17.5	99.7	0.286	0.202	29.47	0.135	52.76
38	131.5	37.7	93.9	0.270	0.214	20.51	0.135	49.84
39	144.3	40.6	103.6	0.298	0.225	24.49	0.135	54.57
40	52.6	21.8	30.8	0.093	0.120	-29.08	0.211	-125.84
41	66.0	29.6	36.4	0.110	0.135	-22.80	0.211	-91.22
42	105.4	58.7	46.7	0.142	0.172	-21.55	0.211	-48.77
43	113.6	64.0	49.7	0.151	0.179	-18.86	0.211	-39.94
44	142.9	87.4	55.5	0.168	0.201	-19.69	0.211	-25.26
45	114.4	54.6	59.8	0.181	0.204	-12.54	0.122	32.57
46	143.4	65.5	77.9	0.236	0.229	2.99	0.122	48.27
47	164.6	71.8	92.9	0.281	0.246	12.66	0.122	56.62
48	182.1	93.6	88.5	0.268	0.259	3.41	0.122	54.44

Table - 7.4.6 (contd.)

No.	a_v pred. (m^2/m^3)	a_p exp. (m^2/m^3)	a_{st} obs. (m^2/m^3)	a_{st}/a_t obs.	a_{st}/a_t pred. This work	% err This work	a_{st}/a_t pred. Puranik & Vogelpohl	% err Puranik & Vogelpohl
49	208.2	109.2	99.0	0.300	0.277	7.50	0.122	59.28
50	229.0	124.8	104.2	0.316	0.291	7.74	0.122	61.33
51	247.0	131.0	115.9	0.351	0.303	13.78	0.122	65.24
52	310.5	188.8	121.7	0.369	0.341	7.61	0.122	66.89
53	97.1	64.2	33.0	0.159	0.156	2.24	0.037	76.62
54	111.5	82.8	28.7	0.139	0.167	-20.51	0.037	73.16
55	123.3	89.0	34.3	0.166	0.176	-6.26	0.037	77.52
56	141.0	105.6	35.4	0.171	0.189	-10.34	0.037	78.22
57	155.1	124.2	30.9	0.149	0.198	-32.68	0.037	75.06
58	199.4	109.2	90.2	0.273	0.223	18.53	0.139	49.07
59	165.6	90.5	75.2	0.228	0.198	12.95	0.160	29.93
60	135.9	78.0	57.9	0.176	0.192	-9.15	0.186	-5.94
61	91.1	49.9	41.2	0.125	0.126	-0.98	0.197	-58.11
62	115.0	65.5	49.5	0.150	0.142	5.17	0.197	-31.74
63	145.1	90.5	54.6	0.165	0.160	3.17	0.197	-19.35
64	132.1	74.9	57.2	0.173	0.153	11.90	0.197	-13.98
65	89.8	49.9	39.9	0.121	0.112	7.70	0.172	-41.79
66	113.4	65.5	47.8	0.145	0.126	13.18	0.172	-18.33
67	130.2	74.9	55.3	0.168	0.135	19.36	0.172	-2.36
68	143.0	90.5	52.5	0.159	0.142	10.92	0.172	-7.73
69	74.0	31.1	42.9	0.123	0.145	-17.96	0.221	-79.07
70	74.0	27.6	46.4	0.133	0.145	-8.85	0.221	-65.67
71	74.4	26.6	47.8	0.137	0.146	-6.38	0.221	-60.46
72	73.6	28.2	45.4	0.131	0.145	-11.30	0.221	-69.00
73	93.4	39.1	54.3	0.156	0.165	-5.46	0.220	-41.18
74	93.7	40.5	53.2	0.153	0.165	-7.90	0.220	-44.28
75	92.0	38.8	53.2	0.153	0.162	-6.10	0.221	-44.37
76	90.3	34.9	55.3	0.159	0.161	-0.92	0.221	-38.83
77	92.0	32.1	59.9	0.172	0.162	5.95	0.221	-28.40
78	55.8	19.6	36.2	0.104	0.127	-22.63	0.220	-111.83
79	74.3	27.9	46.4	0.133	0.148	-11.07	0.220	-64.95
80	74.7	27.0	47.7	0.137	0.146	-6.68	0.221	-60.95
81	74.7	28.3	46.4	0.133	0.146	-9.92	0.221	-65.60
82	73.4	24.3	49.1	0.141	0.145	-2.72	0.221	-56.47
83	94.3	45.4	48.9	0.140	0.166	-18.16	0.220	-56.88
84	94.1	36.4	57.7	0.166	0.166	0.00	0.220	-32.96
85	92.2	37.2	55.0	0.158	0.163	-3.20	0.221	-39.63
86	93.3	31.5	61.8	0.178	0.164	7.72	0.221	-24.14
87	93.5	34.1	59.4	0.171	0.164	3.80	0.221	-29.19
88	45.6	23.1	22.5	0.115	0.090	21.89	0.115	0.00
89	46.3	27.2	19.1	0.098	0.091	6.59	0.115	-17.24
90	45.5	23.9	21.6	0.111	0.091	18.25	0.115	-3.65
91	45.2	26.5	18.7	0.096	0.090	5.84	0.115	-20.07
92	46.3	27.2	19.1	0.098	0.092	5.94	0.114	-16.68
93	46.3	30.7	15.5	0.080	0.092	-15.76	0.115	-43.78
94	46.2	30.9	15.3	0.079	0.092	-17.28	0.114	-45.57
95	45.9	27.2	18.7	0.096	0.092	4.30	0.114	-19.26
96	46.4	27.1	19.3	0.099	0.092	6.68	0.114	-15.54
97	46.3	30.5	15.8	0.081	0.091	-12.18	0.115	-41.98
98	47.0	24.6	22.4	0.115	0.091	20.33	0.115	0.00
99	46.1	26.1	20.0	0.102	0.091	11.22	0.115	-12.30
100	59.6	41.6	18.0	0.092	0.104	-13.10	0.115	-24.12

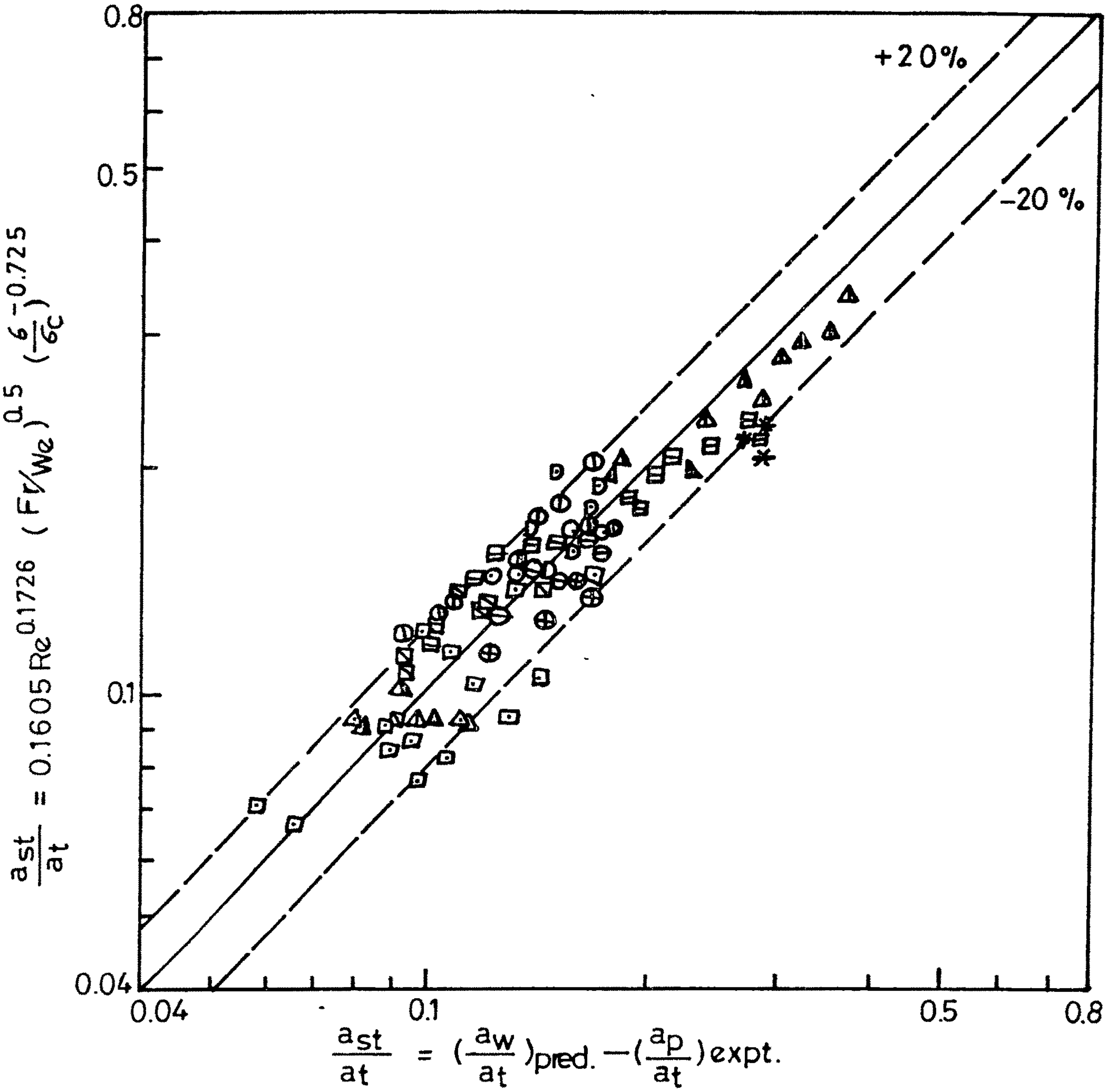

Fig. 7.4. STATIC AREA IN PACKED COLUMN.
COMPARISON OF PREDICTED vs. CALCULATED VALUES.

LEGENDS FOR FIG. 7.4

Data No.	Relevant Information	Symbol
1-6	Fellinger (13), NH_3-Water, C.R.R., 25mm.	⧅
7-36	Yoshida (14), CO_2-Water, C.R.R., 25mm, 15mm.	□ ⊟
37-39	Yoshida (14), CO_2-Methanol,C.R.R., 15mm.	*
40-44	Hikita (15), CO_2-Water, C.R.R., 15mm.	⦶
45-57	Hikita (15), CO_2-Methanol, C.R.R., 15mm, 25mm.	⚠ D
58-60	Hikita (15), CO_2-aq.Methanol, C.R.R., d_p=15mm, Methanol concentrations, 60%, 30%, 10%.	◺ ◣ ⊿
61-68	Hikita (15), CO_2-cane sugar solution, C.R.R., d_p=15mm, sugar concentrations, 5%, 10%.	⊖ ⊕
69-100	Yoshida (16,17), Methanol vapour-Water, C.R.R., 15mm, 25mm.	○ Δ

in literature for predicting the values of a_{st}. The values of (a_{st}/a_t) predicted by the correlation of Puranik and Vogelpohl are also reported in Table (7.4.6). The detailed statistical analysis of this correlation can be described as follows :-

(i) The values of % E_{abs}, % E_{avg} and % S_{dev} were 40.98, -15.93 and 8.23 respectively.

(ii) Out of 100 data points of the observed values of (a_{st}/a_t) only 14 % of the predicted values were within ± 10 % of the observed value, 21 % were within ± 15 % and 39 % were within ± 25 %.

The comparison of statistical analysis for both these generalised correlations reveals that the values of % E_{abs} for the correlation of Puranik and Vogelpohl and that developed in this investigation [Equation (7.16)] are 40.98 and 12.34 respectively. The corresponding values of % E_{avg} are -15.93 and -0.4 respectively and the corresponding values of % S_{dev} are 8.23 and 2.42 respectively. Hence, it can be concluded that the generalised correlation developed in this investigation is expected to be superior in comparison to the existing generalised correlation of Puranik and Vogelpohl.

The lack of data fit in the generalised correlation of Puranik and Vogelpohl may be attributed to the following reasons :-

(i) As has been already discussed in Chapter (6) section 6.1.5 the quantification of staticarea as $a_{st} = (a_c - a_p)$ under certain conditions appears to be inappropriate. Hence, the static area model based on this approach is expected to generate under certain conditions, the wrong observed values of a_{st}. Necessarily the data fit obtained by this correlation is expected to be inferior.

(ii) For the mathematical modelling of data for a_{st}, only a single model parameter - namely (We/Fr) was used by these investigators. As has been also discussed in Chapter (6), the values of a_{st} do get affected by altering the values of L, μ_L, and (σ / σ_c). Hence the additional model parameters like Re and (σ / σ_c) should have been included by these investigators in their generalised correlation.

7.5.0 PREDICTION OF INTERFACIAL AREAS :

Thus, in the present chapter (7) a software package developed in this investigation the salient features of which have been mentioned in Chapter (3), has been successfully used to perform mathematical modelling of data on interfacial areas.

The following generalised correlation [Equation (7.3)] could be used satisfactorily to predict the value of wetted surface area :-

$$a_w/a_t = 1.431 \; (Re)^{0.0014} \; (We)^{0.165} \; (Fr)^{0.002} \; (\sigma / \sigma_c)^{-0.442}$$

The following generalised correlation [Equation (7.7)] can be used to predict the values of interfacial area during physical absorption :-

$$a_p/a_t = 1.08 \; (Re)^{0.099} \; (We)^{0.22} \; (Fr)^{0.002} \; (\sigma / \sigma_c)^{-0.442}$$

Further, the following generalised correlation can also be used satisfactorily to predict the values of (a_w/a_t) and (a_p/a_t) by using appropriate values of index for 'We' :-

$$a_w/a_t \text{ or } a_p/a_t = 1.431\ (Re)^{0.0014}\ (We)^{\beta}\ (Fr)^{0.002}\ (\sigma / \sigma_c)^{-0.442}$$

where β = 0.165 for wetted surface area and 0.237 for physical absorption.

The following generalised correlation [Equation (7.10)] could be utilised to predict the values of effective interfacial area during chemical absorption :-

$$a_c/a_t = 0.455\ (Re)^{0.227}\ (We)^{0.058}\ (Fr)^{0.002}\ (\sigma / \sigma_c)^{-1.104}$$

The values of (a_{st}/a_t) can be predicted satisfactorily by the following generalised correlation [Equation (7.16)] :-

$$a_{st}/a_t = 0.1605\ (Re)^{0.1726}\ (Fr/We)^{0.5}\ (\sigma / \sigma_c)^{-0.725}$$

The static area model developed in this investigation can be used successfully to predict the values of (a_p/a_t) by using the following correlation :-

$$a_p/a_t = (a_w/a_t)_{pred} - (a_{st}/a_t)_{pred} \qquad (7.21)$$

The detailed statistical analysis of the correlation is as under :-

$\%\ E_{avg}$ = 4.76, $\%\ E_{abs}$ = 18.23 and $\%\ S_{dev}$ = 5.04.

Using equations (7.3) and (7.16) one can predict the values of (a_w/a_t) and (a_{st}/a_t) under otherwise identical conditions and then substracting (a_{st}/a_t) from (a_w/a_t), the values of (a_p/a_t) can be predicted. This generalised correlation [Equation (7.21)] developed in this investigation is not merely an empirical correlation but it elucidates the mechanism of mass transfer during physical absorption.

The static area model developed in this investigation can also be used successfully to predict the values of (a_c/a_t) by using the following correlation :-

$$a_c/a_t = (a_p/a_t)_{pred} + (a_{st}/a_t)_{pred} \tag{7.22}$$

The detailed statistical analysis of the correlation is as under :

$$\%\ E_{avg} = 2.29,\ \%\ E_{abs} = 20.28 \text{ and } \%\ S_{dev} = 0.95$$

Using equation (7.7) and (7.16) one can predict the values of (a_p/a_t) and (a_{st}/a_t) under otherwise identical conditions and then adding (a_p/a_t) to (a_{st}/a_t), the values of (a_c/a_t) can be predicted. This additional generalised correlation [Equation (7.22)] developed in this investigation is not merely an empirical correlation but it also eludicates the mechanism of mass transfer during chemical absorption.

Thus, the static area model developed in this investigation (186, 187) could be utilised conveniently for predicting the values of effective interfacial areas during physical absorption as well as during chemical absorption.