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APPENDICES

Appendix : A	Percentage Points of the F Distribution ^[6]
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Appendix A : Percentage Points of the F Distribution^a

$$F_{0.25, df_1, df_2}$$

df_2	Degrees of Freedom for the Numerator (df_1)																		
	1	2	3	4	5	6	7	8	9	10	12	15	20	24	30	40	60	120	∞
1	5.83	7.50	8.20	8.58	8.62	8.98	9.10	9.19	9.28	9.32	9.41	9.49	9.58	9.63	9.67	9.71	9.76	9.80	9.65
2	2.57	3.00	3.15	3.23	3.28	3.31	3.34	3.35	3.37	3.38	3.39	3.41	3.43	3.43	3.44	3.45	3.46	3.47	3.48
3	2.02	2.28	2.36	2.39	2.41	2.42	2.43	2.44	2.44	2.44	2.45	2.48	2.46	2.46	2.47	2.47	2.47	2.47	2.47
4	1.81	2.00	2.05	2.06	2.07	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
5	1.69	1.85	1.88	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.88	1.88	1.88	1.88	1.87	1.87	1.87
6	1.62	1.76	1.78	1.79	1.79	1.78	1.78	1.78	1.77	1.77	1.77	1.76	1.76	1.75	1.75	1.75	1.74	1.74	1.74
7	1.57	1.70	1.72	1.72	1.71	1.71	1.70	1.70	1.70	1.69	1.68	1.68	1.67	1.67	1.66	1.66	1.65	1.65	1.65
8	1.54	1.66	1.67	1.66	1.66	1.65	1.64	1.64	1.63	1.63	1.62	1.62	1.61	1.60	1.60	1.59	1.59	1.58	1.58
9	1.51	1.62	1.63	1.63	1.62	1.61	1.60	1.60	1.59	1.59	1.58	1.57	1.56	1.56	1.55	1.54	1.54	1.53	1.53
10	1.49	1.60	1.60	1.59	1.59	1.58	1.57	1.56	1.56	1.55	1.54	1.53	1.52	1.52	1.51	1.51	1.50	1.49	1.48
11	1.47	1.58	1.58	1.57	1.58	1.55	1.54	1.53	1.53	1.52	1.51	1.50	1.49	1.49	1.48	1.47	1.47	1.46	1.45
12	1.46	1.56	1.56	1.55	1.54	1.53	1.52	1.51	1.51	1.50	1.49	1.48	1.47	1.48	1.45	1.45	1.44	1.43	1.42
13	1.45	1.55	1.55	1.53	1.52	1.51	1.50	1.49	1.49	1.48	1.47	1.46	1.45	1.44	1.43	1.42	1.42	1.41	1.40
14	1.44	1.53	1.53	1.52	1.51	1.50	1.49	1.48	1.47	1.46	1.45	1.44	1.43	1.42	1.41	1.41	1.40	1.39	1.38
15	1.43	1.52	1.52	1.51	1.49	1.48	1.47	1.46	1.46	1.45	1.44	1.43	1.41	1.41	1.40	1.39	1.38	1.37	1.36
16	1.42	1.51	1.51	1.50	1.48	1.47	1.46	1.45	1.44	1.44	1.43	1.41	1.40	1.39	1.38	1.37	1.36	1.35	1.34
17	1.42	1.51	1.50	1.49	1.47	1.46	1.45	1.44	1.43	1.43	1.41	1.40	1.39	1.38	1.37	1.36	1.35	1.34	1.33
18	1.41	1.50	1.49	1.48	1.46	1.45	1.44	1.43	1.42	1.42	1.40	1.39	1.38	1.37	1.36	1.35	1.34	1.33	1.32
19	1.41	1.49	1.49	1.47	1.46	1.44	1.43	1.42	1.41	1.41	1.40	1.38	1.37	1.36	1.35	1.34	1.33	1.32	1.30
20	1.40	1.49	1.48	1.47	1.45	1.44	1.43	1.42	1.41	1.40	1.39	1.37	1.36	1.35	1.34	1.33	1.32	1.31	1.29
21	1.40	1.48	1.48	1.46	1.44	1.43	1.42	1.41	1.40	1.39	1.38	1.37	1.35	1.34	1.33	1.32	1.31	1.30	1.28
22	1.40	1.48	1.47	1.45	1.44	1.42	1.41	1.40	1.39	1.39	1.37	1.36	1.34	1.33	1.32	1.31	1.30	1.29	1.28
23	1.39	1.47	1.47	1.45	1.43	1.42	1.41	1.40	1.39	1.38	1.37	1.35	1.34	1.33	1.32	1.31	1.30	1.28	1.27
24	1.39	1.47	1.46	1.44	1.43	1.41	1.40	1.39	1.38	1.38	1.36	1.35	1.33	1.32	1.31	1.30	1.29	1.28	1.26
25	1.39	1.47	1.46	1.44	1.42	1.41	1.40	1.39	1.38	1.37	1.36	1.34	1.33	1.32	1.31	1.29	1.28	1.27	1.25
26	1.38	1.46	1.45	1.44	1.42	1.41	1.39	1.38	1.37	1.37	1.36	1.34	1.32	1.31	1.30	1.29	1.28	1.28	1.25
27	1.38	1.46	1.45	1.43	1.42	1.40	1.39	1.38	1.37	1.36	1.35	1.33	1.32	1.31	1.30	1.28	1.27	1.26	1.24
28	1.38	1.46	1.45	1.43	1.41	1.40	1.39	1.38	1.37	1.36	1.34	1.33	1.31	1.30	1.29	1.28	1.27	1.25	1.24
29	1.38	1.45	1.45	1.43	1.41	1.40	1.38	1.37	1.36	1.35	1.34	1.32	1.31	1.30	1.29	1.27	1.26	1.25	1.23
30	1.38	1.45	1.44	1.42	1.41	1.39	1.38	1.37	1.36	1.35	1.34	1.32	1.30	1.29	1.28	1.27	1.26	1.24	1.23
40	1.36	1.44	1.42	1.40	1.39	1.37	1.36	1.35	1.34	1.33	1.31	1.30	1.26	1.26	1.25	1.24	1.22	1.21	1.19
60	1.35	1.42	1.41	1.38	1.37	1.35	1.33	1.32	1.31	1.30	1.29	1.27	1.25	1.24	1.22	1.21	1.19	1.17	1.15
120	1.34	1.40	1.39	1.37	1.36	1.33	1.31	1.30	1.29	1.28	1.28	1.24	1.22	1.21	1.19	1.18	1.16	1.13	1.10
∞	1.32	1.39	1.37	1.35	1.33	1.31	1.29	1.28	1.27	1.25	1.24	1.22	1.19	1.18	1.16	1.14	1.12	1.08	1.00

df = degrees of freedom

^a Adapted with permission from *Biometrika Tables for Statisticians*, Vol. 1, 3rd edition by E. S. Pearson and H. O. Hartley, Cambridge University Press, Cambridge, 1996.

Appendix A : Percentage Points of the F Distribution^a (continued)

$$F_{0.10, df_1, df_2}$$

df ₂	Degrees of Freedom for the Numerator (df ₁)																		
	1	2	3	4	5	6	7	8	9	10	12	15	20	24	30	40	80	120	∞
1	39.06	49.50	53.59	55.83	57.24	58.20	58.91	59.44	59.86	60.19	60.71	61.22	61.74	62.00	62.26	62.53	62.79	63.08	63.33
2	6.53	9.00	9.16	9.24	9.29	9.33	9.35	9.37	9.38	9.39	9.41	9.42	9.44	9.45	9.46	9.47	9.47	9.48	9.49
3	5.54	5.46	5.39	5.34	5.31	5.28	5.27	5.25	5.24	5.23	5.22	5.20	5.18	5.16	5.17	5.16	5.15	5.14	5.13
4	4.54	4.32	4.19	4.11	4.05	4.01	3.98	3.95	3.94	3.92	3.90	3.87	3.84	3.83	3.82	3.80	3.79	3.78	3.76
5	4.06	3.78	3.62	3.52	3.45	3.40	3.37	3.34	3.32	3.30	3.27	3.24	3.21	3.19	3.17	3.16	3.14	3.12	3.10
6	3.78	3.46	3.29	3.18	3.11	3.05	3.01	2.98	2.96	2.94	2.90	2.87	2.84	2.82	2.80	2.78	2.76	2.74	2.72
7	3.59	3.28	3.07	2.96	2.88	2.83	2.78	2.75	2.72	2.70	2.67	2.63	2.59	2.56	2.54	2.51	2.49	2.47	2.44
8	3.46	3.11	2.92	2.81	2.73	2.67	2.62	2.59	2.56	2.54	2.50	2.48	2.42	2.40	2.38	2.36	2.34	2.32	2.29
9	3.36	3.01	2.81	2.69	2.61	2.55	2.51	2.47	2.44	2.42	2.38	2.34	2.30	2.28	2.25	2.23	2.21	2.18	2.16
10	3.29	2.92	2.73	2.61	2.52	2.46	2.41	2.38	2.35	2.32	2.28	2.24	2.20	2.18	2.16	2.13	2.11	2.08	2.06
11	3.23	2.86	2.66	2.54	2.45	2.39	2.34	2.30	2.27	2.25	2.21	2.17	2.12	2.09	2.08	2.05	2.03	2.00	1.97
12	3.18	2.81	2.61	2.48	2.39	2.33	2.28	2.24	2.21	2.19	2.15	2.10	2.06	2.04	2.01	1.99	1.96	1.93	1.90
13	3.14	2.78	2.56	2.43	2.35	2.28	2.23	2.20	2.16	2.14	2.10	2.05	2.01	1.98	1.96	1.93	1.90	1.88	1.85
14	3.10	2.73	2.52	2.39	2.31	2.24	2.19	2.15	2.12	2.10	2.05	2.01	1.96	1.94	1.91	1.89	1.86	1.83	1.80
15	3.07	2.70	2.49	2.36	2.27	2.21	2.16	2.12	2.09	2.06	2.02	1.97	1.92	1.90	1.87	1.85	1.82	1.79	1.76
16	3.05	2.67	2.46	2.33	2.24	2.18	2.13	2.09	2.06	2.03	1.99	1.94	1.89	1.87	1.84	1.81	1.78	1.75	1.72
17	3.03	2.64	2.44	2.31	2.22	2.15	2.10	2.06	2.03	2.00	1.96	1.91	1.86	1.84	1.81	1.78	1.75	1.72	1.69
18	3.01	2.62	2.42	2.29	2.20	2.13	2.08	2.04	2.00	1.98	1.93	1.89	1.84	1.81	1.78	1.75	1.72	1.69	1.66
19	2.99	2.61	2.40	2.27	2.18	2.11	2.06	2.02	1.98	1.96	1.91	1.86	1.81	1.79	1.78	1.73	1.70	1.67	1.63
20	2.97	2.59	2.38	2.25	2.16	2.09	2.04	2.00	1.96	1.94	1.89	1.84	1.79	1.77	1.74	1.71	1.68	1.64	1.61
21	2.96	2.57	2.36	2.23	2.14	2.08	2.02	1.98	1.95	1.92	1.87	1.83	1.78	1.75	1.72	1.69	1.66	1.62	1.59
22	2.95	2.56	2.35	2.22	2.13	2.06	2.01	1.97	1.93	1.90	1.86	1.81	1.76	1.73	1.70	1.67	1.64	1.60	1.57
23	2.94	2.55	2.34	2.21	2.11	2.05	1.99	1.95	1.92	1.89	1.84	1.80	1.74	1.72	1.69	1.66	1.62	1.59	1.55
24	2.93	2.54	2.33	2.19	2.10	2.04	1.98	1.94	1.91	1.88	1.83	1.78	1.73	1.70	1.67	1.64	1.61	1.57	1.53
25	2.92	2.53	2.32	2.18	2.09	2.02	1.97	1.93	1.89	1.87	1.82	1.77	1.72	1.69	1.66	1.63	1.59	1.56	1.52
26	2.91	2.52	2.31	2.17	2.08	2.01	1.96	1.92	1.88	1.86	1.81	1.76	1.71	1.68	1.65	1.61	1.58	1.54	1.50
27	2.90	2.51	2.30	2.17	2.07	2.00	1.95	1.91	1.87	1.85	1.80	1.75	1.70	1.67	1.64	1.60	1.57	1.53	1.49
28	2.89	2.50	2.29	2.16	2.06	2.00	1.94	1.90	1.87	1.84	1.79	1.74	1.69	1.66	1.63	1.59	1.56	1.52	1.48
29	2.89	2.50	2.28	2.15	2.06	1.99	1.93	1.89	1.86	1.83	1.78	1.73	1.68	1.65	1.62	1.58	1.55	1.51	1.47
30	2.88	2.49	2.28	2.14	2.03	1.98	1.93	1.88	1.85	1.82	1.77	1.72	1.67	1.64	1.61	1.57	1.54	1.50	1.46
40	2.84	2.44	2.23	2.09	2.00	1.93	1.87	1.83	1.79	1.76	1.71	1.66	1.61	1.57	1.54	1.51	1.47	1.42	1.38
60	2.79	2.39	2.18	2.04	1.95	1.87	1.82	1.77	1.74	1.71	1.66	1.60	1.54	1.51	1.48	1.44	1.40	1.35	1.29
120	2.75	2.35	2.13	1.99	1.90	1.82	1.77	1.72	1.68	1.65	1.60	1.55	1.48	1.45	1.41	1.37	1.32	1.26	1.19
∞	2.71	2.30	2.08	1.94	1.85	1.77	1.72	1.67	1.63	1.60	1.55	1.49	1.42	1.38	1.34	1.30	1.24	1.17	1.00

Appendix A : Percentage Points of the F Distribution^a (continued)

$F_{0.05, df_1, df_2}$

df_2	Degrees of Freedom for the Numerator (df_1)																		
	1	2	3	4	5	6	7	8	9	10	12	15	20	24	30	40	60	120	∞
1	161.4	199.5	215.7	224.6	230.2	234	236.8	238.9	240.5	241.9	243.9	245.9	248.0	249.1	250.1	251.1	252.2	253.3	254.3
2	18.51	19.00	19.16	19.25	19.30	19.33	19.35	19.37	19.38	19.40	19.41	19.43	19.45	19.45	19.46	19.47	19.48	19.49	19.50
3	10.13	9.55	9.28	9.12	9.01	8.94	8.89	8.85	8.81	8.79	8.74	8.70	8.66	8.64	8.62	8.59	8.57	8.55	8.53
4	7.71	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00	5.98	5.91	5.86	5.80	5.77	5.75	5.72	5.69	5.66	5.63
5	6.61	5.79	5.41	5.19	5.05	4.95	4.88	4.82	4.77	4.74	4.68	4.62	4.56	4.53	4.50	4.46	4.43	4.40	4.38
6	5.99	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10	4.06	4.00	3.94	3.87	3.84	3.81	3.77	3.74	3.70	3.67
7	5.59	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.66	3.64	3.57	3.51	3.44	3.41	3.38	3.34	3.30	3.27	3.23
8	5.32	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39	3.35	3.28	3.22	3.15	3.12	3.08	3.04	3.01	2.97	2.93
9	5.12	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18	3.14	3.07	3.01	2.94	2.90	2.86	2.83	2.79	2.75	2.71
10	4.96	4.10	3.71	3.48	3.33	3.22	3.14	3.07	3.02	2.98	2.91	2.85	2.77	2.74	2.70	2.66	2.62	2.58	2.54
11	4.84	3.98	3.59	3.36	3.20	3.09	3.01	2.95	2.90	2.85	2.79	2.72	2.65	2.61	2.57	2.53	2.49	2.45	2.40
12	4.75	3.89	3.49	3.26	3.11	3.00	2.91	2.85	2.80	2.75	2.69	2.62	2.54	2.51	2.47	2.43	2.38	2.34	2.30
13	4.67	3.81	3.41	3.18	3.03	2.92	2.83	2.77	2.71	2.67	2.60	2.53	2.46	2.42	2.38	2.34	2.30	2.25	2.21
14	4.60	3.74	3.34	3.11	2.96	2.85	2.76	2.70	2.65	2.60	2.53	2.46	2.39	2.35	2.31	2.27	2.22	2.18	2.13
15	4.54	3.68	3.29	3.06	2.90	2.79	2.71	2.64	2.59	2.54	2.48	2.40	2.33	2.29	2.25	2.20	2.16	2.11	2.07
16	4.49	3.63	3.24	3.01	2.85	2.74	2.66	2.59	2.54	2.49	2.42	2.35	2.28	2.24	2.19	2.15	2.11	2.06	2.01
17	4.45	3.59	3.20	2.96	2.81	2.70	2.61	2.55	2.49	2.45	2.38	2.31	2.23	2.19	2.15	2.10	2.06	2.01	1.96
18	4.41	3.55	3.16	2.93	2.77	2.66	2.58	2.51	2.46	2.41	2.34	2.27	2.19	2.15	2.11	2.06	2.02	1.97	1.92
19	4.38	3.52	3.13	2.90	2.74	2.63	2.54	2.48	2.42	2.38	2.31	2.23	2.16	2.11	2.07	2.03	1.98	1.93	1.88
20	4.35	3.49	3.10	2.87	2.71	2.60	2.51	2.45	2.39	2.35	2.28	2.20	2.12	2.08	2.04	1.99	1.95	1.90	1.84
21	4.32	3.47	3.07	2.84	2.68	2.57	2.49	2.42	2.37	2.32	2.25	2.18	2.10	2.05	2.01	1.96	1.92	1.87	1.81
22	4.30	3.44	3.05	2.82	2.66	2.55	2.46	2.40	2.34	2.30	2.23	2.15	2.07	2.03	1.98	1.94	1.89	1.84	1.78
23	4.28	3.42	3.03	2.80	2.64	2.53	2.44	2.37	2.32	2.27	2.20	2.13	2.05	2.01	1.96	1.91	1.86	1.81	1.76
24	4.26	3.40	3.01	2.78	2.62	2.51	2.42	2.36	2.30	2.25	2.18	2.11	2.03	1.98	1.94	1.89	1.84	1.79	1.73
25	4.24	3.39	2.99	2.76	2.60	2.49	2.40	2.34	2.28	2.24	2.16	2.09	2.01	1.98	1.92	1.87	1.82	1.77	1.71
26	4.23	3.37	2.98	2.74	2.59	2.47	2.39	2.32	2.27	2.22	2.15	2.07	1.99	1.95	1.90	1.85	1.80	1.75	1.69
27	4.21	3.35	2.96	2.73	2.57	2.46	2.37	2.31	2.25	2.20	2.13	2.06	1.97	1.93	1.88	1.84	1.79	1.73	1.67
28	4.20	3.34	2.95	2.71	2.56	2.45	2.36	2.29	2.24	2.19	2.12	2.04	1.96	1.91	1.87	1.82	1.77	1.71	1.65
29	4.18	3.33	2.93	2.70	2.55	2.43	2.35	2.28	2.22	2.18	2.10	2.03	1.94	1.90	1.85	1.81	1.75	1.70	1.64
30	4.17	3.32	2.92	2.69	2.53	2.42	2.33	2.27	2.21	2.16	2.09	2.01	1.93	1.89	1.84	1.79	1.74	1.68	1.62
40	4.08	3.23	2.84	2.61	2.45	2.34	2.25	2.18	2.12	2.08	2.00	1.92	1.84	1.79	1.74	1.69	1.64	1.58	1.51
60	4.00	3.15	2.76	2.53	2.37	2.25	2.17	2.10	2.04	1.99	1.92	1.84	1.75	1.70	1.65	1.59	1.53	1.47	1.39
120	3.92	3.07	2.68	2.45	2.29	2.17	2.09	2.02	1.96	1.91	1.83	1.75	1.66	1.61	1.55	1.50	1.43	1.35	1.25
∞	3.84	3.00	2.60	2.37	2.21	2.10	2.01	1.94	1.88	1.83	1.75	1.67	1.57	1.52	1.46	1.39	1.32	1.22	1.00

Appendix A : Percentage Points of the F Distribution^a (continued)

$$F_{0.025, df_1, df_2}$$

df ₂ \ df ₁	Degrees of Freedom for the Numerator (df ₁)																		
	1	2	3	4	5	6	7	8	9	10	12	15	20	24	30	40	60	120	∞
1	647.8	799.5	864.2	899.6	921.8	937.1	948.2	956.7	963.3	968.6	978.7	984.9	993.1	997.2	1001	1006	1010	1014	1018
2	38.51	39.00	39.17	39.25	39.30	39.33	39.36	39.37	39.39	39.40	39.41	39.43	39.45	39.46	39.46	39.47	39.48	39.49	39.50
3	17.44	16.04	15.44	15.10	14.88	14.73	14.62	14.54	14.47	14.42	14.34	14.25	14.17	14.12	14.08	14.04	13.99	13.95	13.90
4	12.22	10.65	9.98	9.60	9.36	9.20	9.07	8.98	8.90	8.84	8.75	8.66	8.56	8.51	8.46	8.41	8.36	8.31	8.26
5	10.01	8.43	7.76	7.39	7.15	6.98	6.85	6.76	6.68	6.62	6.52	6.43	6.33	6.28	6.23	6.18	6.12	6.07	6.02
6	8.81	7.26	6.60	6.23	5.99	5.82	5.70	5.60	5.52	5.46	5.37	5.27	5.17	5.12	5.07	5.01	4.96	4.90	4.85
7	8.07	6.54	5.89	5.52	5.29	5.12	4.99	4.90	4.82	4.76	4.67	4.57	4.47	4.42	4.38	4.31	4.25	4.20	4.14
8	7.57	6.06	5.42	5.05	4.82	4.65	4.53	4.43	4.36	4.30	4.20	4.10	4.00	3.95	3.89	3.84	3.78	3.73	3.67
9	7.21	5.71	5.08	4.72	4.48	4.32	4.20	4.10	4.03	3.96	3.87	3.77	3.67	3.61	3.56	3.51	3.45	3.39	3.33
10	6.94	5.46	4.83	4.47	4.24	4.07	3.95	3.85	3.78	3.72	3.62	3.52	3.42	3.37	3.31	3.26	3.20	3.14	3.08
11	6.72	5.26	4.63	4.28	4.04	3.88	3.76	3.66	3.59	3.53	3.43	3.33	3.23	3.17	3.12	3.06	3.00	2.94	2.88
12	6.55	5.10	4.47	4.12	3.89	3.73	3.61	3.51	3.44	3.37	3.28	3.18	3.07	3.02	2.96	2.91	2.85	2.79	2.72
13	6.41	4.97	4.35	4.00	3.77	3.60	3.48	3.39	3.31	3.25	3.15	3.05	2.95	2.89	2.84	2.78	2.72	2.66	2.60
14	6.30	4.86	4.24	3.89	3.66	3.50	3.38	3.29	3.21	3.15	3.05	2.95	2.84	2.79	2.73	2.67	2.61	2.55	2.49
15	6.20	4.77	4.15	3.80	3.58	3.41	3.29	3.20	3.12	3.06	2.96	2.86	2.76	2.70	2.64	2.59	2.52	2.46	2.40
16	6.12	4.69	4.08	3.73	3.50	3.34	3.22	3.12	3.05	2.99	2.89	2.79	2.68	2.63	2.57	2.51	2.45	2.38	2.32
17	6.04	4.62	4.01	3.66	3.44	3.28	3.16	3.06	2.98	2.92	2.82	2.72	2.62	2.56	2.50	2.44	2.38	2.32	2.25
18	5.98	4.56	3.95	3.61	3.38	3.22	3.10	3.01	2.93	2.87	2.77	2.67	2.56	2.50	2.44	2.38	2.32	2.26	2.19
19	5.92	4.51	3.90	3.56	3.33	3.17	3.05	2.96	2.88	2.82	2.72	2.62	2.51	2.45	2.39	2.33	2.27	2.20	2.13
20	5.87	4.46	3.86	3.51	3.29	3.13	3.01	2.91	2.84	2.77	2.68	2.57	2.46	2.41	2.35	2.29	2.22	2.16	2.09
21	5.83	4.42	3.82	3.48	3.25	3.09	2.97	2.87	2.80	2.73	2.64	2.53	2.42	2.37	2.31	2.25	2.18	2.11	2.04
22	5.79	4.38	3.78	3.44	3.22	3.05	2.93	2.84	2.76	2.70	2.60	2.50	2.39	2.33	2.27	2.21	2.14	2.08	2.00
23	5.75	4.35	3.75	3.41	3.18	3.02	2.90	2.81	2.73	2.67	2.57	2.47	2.36	2.30	2.24	2.18	2.11	2.04	1.97
24	5.72	4.32	3.72	3.38	3.15	2.99	2.87	2.78	2.70	2.64	2.54	2.44	2.33	2.27	2.21	2.15	2.08	2.01	1.94
25	5.69	4.29	3.69	3.35	3.13	2.97	2.85	2.75	2.68	2.61	2.51	2.41	2.30	2.24	2.18	2.12	2.05	1.98	1.91
26	5.66	4.27	3.67	3.33	3.10	2.94	2.82	2.73	2.65	2.59	2.49	2.39	2.28	2.22	2.16	2.09	2.03	1.95	1.88
27	5.63	4.24	3.65	3.31	3.08	2.92	2.80	2.71	2.63	2.57	2.47	2.36	2.25	2.19	2.13	2.07	2.00	1.93	1.85
28	5.61	4.22	3.63	3.29	3.06	2.90	2.78	2.69	2.61	2.55	2.45	2.34	2.23	2.17	2.11	2.05	1.98	1.91	1.83
29	5.59	4.20	3.61	3.27	3.04	2.88	2.76	2.67	2.59	2.53	2.43	2.32	2.21	2.15	2.09	2.03	1.96	1.89	1.81
30	5.57	4.18	3.59	3.25	3.03	2.87	2.75	2.65	2.57	2.51	2.41	2.31	2.20	2.14	2.07	2.01	1.94	1.87	1.79
40	5.42	4.06	3.46	3.13	2.90	2.74	2.62	2.53	2.45	2.39	2.29	2.18	2.07	2.01	1.94	1.88	1.80	1.72	1.64
60	5.29	3.93	3.34	3.01	2.79	2.63	2.51	2.41	2.33	2.27	2.17	2.06	1.94	1.88	1.82	1.74	1.67	1.58	1.48
120	5.15	3.80	3.23	2.89	2.67	2.52	2.39	2.30	2.22	2.16	2.05	1.94	1.82	1.76	1.69	1.61	1.53	1.43	1.31
∞	5.02	3.69	3.12	2.79	2.57	2.41	2.29	2.19	2.11	2.05	1.94	1.83	1.71	1.64	1.57	1.48	1.39	1.27	1.00

Appendix A : Percentage Points of the F Distribution^a (continued)

$F_{0.01, df_1, df_2}$

df_2 \ df_1	Degrees of Freedom for the Numerator (df_1)																		
	1	2	3	4	5	6	7	8	9	10	12	15	20	24	30	40	60	120	∞
1	4052	4999.5	5403	5625	5784	5859	5928	5982	6022	6058	6106	6157	6209	6236	6261	6287	6313	6339	6366
2	98.50	99.00	99.17	99.25	99.30	99.33	99.36	99.37	99.39	99.40	99.42	99.43	99.45	99.46	99.47	99.47	99.48	99.49	99.50
3	34.12	30.62	29.46	28.71	28.24	27.91	27.67	27.49	27.35	27.23	27.05	26.87	26.69	26.00	26.50	26.41	26.32	26.22	26.13
4	21.20	18.00	16.69	15.98	15.52	15.21	14.98	14.80	14.66	14.55	14.37	14.20	14.02	13.93	13.84	13.75	13.65	13.56	13.46
5	16.28	13.27	12.06	11.39	10.97	10.67	10.46	10.29	10.16	10.05	9.89	9.72	9.55	9.47	9.38	9.29	9.20	9.11	9.02
6	13.75	10.92	9.78	9.15	8.75	8.47	8.28	8.10	7.98	7.87	7.72	7.56	7.40	7.31	7.23	7.14	7.06	6.97	6.88
7	12.25	9.55	8.45	7.85	7.46	7.19	6.99	6.84	6.72	6.62	6.47	6.31	6.18	6.07	5.99	5.91	5.82	5.74	5.65
8	11.28	8.65	7.59	7.01	6.63	6.37	6.18	6.03	5.91	5.81	5.67	5.52	5.36	5.28	5.20	5.12	5.03	4.95	4.86
9	10.56	8.02	6.99	6.42	6.06	5.80	5.61	5.47	5.35	5.26	5.11	4.96	4.81	4.73	4.65	4.57	4.48	4.40	4.31
10	10.04	7.56	6.55	5.99	5.64	5.39	5.20	5.06	4.94	4.85	4.71	4.58	4.41	4.33	4.25	4.17	4.08	4.00	3.91
11	9.65	7.21	6.22	5.67	5.32	5.07	4.89	4.74	4.63	4.54	4.40	4.25	4.10	4.02	3.94	3.86	3.78	3.69	3.60
12	9.33	6.93	5.95	5.41	5.08	4.82	4.64	4.50	4.39	4.30	4.16	4.01	3.86	3.78	3.70	3.62	3.54	3.45	3.36
13	9.07	6.70	5.74	5.21	4.86	4.62	4.44	4.30	4.19	4.10	3.96	3.82	3.66	3.59	3.51	3.43	3.34	3.25	3.17
14	8.86	6.51	5.56	5.04	4.69	4.46	4.28	4.14	4.03	3.94	3.80	3.66	3.51	3.43	3.35	3.27	3.18	3.09	3.00
15	8.68	6.36	5.42	4.89	4.56	4.32	4.14	4.00	3.89	3.80	3.67	3.52	3.37	3.29	3.21	3.13	3.05	2.96	2.87
16	8.53	6.23	5.29	4.77	4.44	4.20	4.03	3.89	3.78	3.69	3.55	3.41	3.26	3.18	3.10	3.02	2.93	2.84	2.85
17	8.40	6.11	5.18	4.67	4.34	4.10	3.93	3.79	3.68	3.59	3.46	3.31	3.16	3.08	3.00	2.92	2.83	2.75	2.65
18	8.29	6.01	5.09	4.56	4.25	4.01	3.84	3.71	3.60	3.51	3.37	3.23	3.08	3.00	2.92	2.84	2.75	2.66	2.57
19	8.18	5.93	5.01	4.50	4.17	3.94	3.77	3.63	3.52	3.43	3.30	3.15	3.00	2.92	2.84	2.76	2.67	2.58	2.49
20	8.10	5.85	4.94	4.43	4.10	3.87	3.70	3.55	3.46	3.37	3.23	3.09	2.94	2.86	2.78	2.69	2.61	2.52	2.42
21	8.02	5.78	4.87	4.37	4.04	3.81	3.64	3.51	3.40	3.31	3.17	3.03	2.88	2.80	2.72	2.64	2.55	2.46	2.36
22	7.95	5.72	4.82	4.31	3.99	3.76	3.59	3.45	3.35	3.26	3.12	2.98	2.83	2.75	2.67	2.58	2.50	2.40	2.31
23	7.88	5.66	4.76	4.26	3.94	3.71	3.54	3.41	3.30	3.21	3.07	2.93	2.78	2.70	2.62	2.54	2.45	2.35	2.26
24	7.82	5.61	4.72	4.22	3.90	3.67	3.50	3.36	3.26	3.17	3.03	2.89	2.74	2.66	2.58	2.49	2.40	2.31	2.21
25	7.77	5.57	4.68	4.18	3.85	3.63	3.46	3.32	3.22	3.13	2.99	2.85	2.70	2.62	2.54	2.45	2.36	2.27	2.17
26	7.72	5.53	4.64	4.14	3.82	3.59	3.42	3.29	3.18	3.09	2.96	2.81	2.66	2.58	2.50	2.42	2.33	2.23	2.13
27	7.68	5.49	4.60	4.11	3.78	3.56	3.39	3.26	3.15	3.06	2.93	2.78	2.63	2.55	2.47	2.38	2.29	2.20	2.10
28	7.64	5.45	4.57	4.07	3.75	3.53	3.36	3.23	3.12	3.03	2.90	2.75	2.60	2.52	2.44	2.35	2.26	2.17	2.08
29	7.60	5.42	4.54	4.04	3.73	3.50	3.33	3.20	3.09	3.00	2.87	2.73	2.57	2.49	2.41	2.33	2.23	2.14	2.03
30	7.56	5.39	4.51	4.02	3.70	3.47	3.30	3.17	3.07	2.98	2.84	2.70	2.55	2.47	2.39	2.30	2.21	2.11	2.01
40	7.31	5.18	4.31	3.83	3.51	3.29	3.12	2.99	2.89	2.80	2.66	2.52	2.37	2.29	2.20	2.11	2.02	1.92	1.80
60	7.08	4.98	4.13	3.65	3.34	3.12	2.95	2.82	2.72	2.63	2.50	2.36	2.20	2.12	2.03	1.94	1.84	1.73	1.60
120	6.85	4.79	3.95	3.46	3.17	2.96	2.79	2.66	2.56	2.47	2.34	2.19	2.03	1.95	1.86	1.76	1.66	1.53	1.38
∞	6.63	4.61	3.78	3.32	3.02	2.80	2.64	2.51	2.41	2.32	2.18	2.04	1.88	1.79	1.70	1.59	1.47	1.32	1.00

Appendix B : Percentage Points of the t Distribution*

α df	0.40	0.25	0.10	0.05	0.025	0.01	0.005	0.0025	0.001	0.0005
1	0.325	1.000	3.078	6.314	12.706	31.821	63.657	127.32	318.31	636.82
2	0.289	0.816	1.886	2.920	4.303	6.965	9.925	14.089	23.326	31.598
3	0.277	0.785	1.838	2.353	3.182	4.541	5.841	7.453	10.213	12.924
4	0.271	0.741	1.533	2.132	2.778	3.747	4.804	5.598	7.173	8.610
5	0.267	0.727	1.476	2.015	2.571	3.385	4.032	4.773	5.893	6.869
6	0.265	0.727	1.440	1.943	2.447	3.143	3.707	4.317	5.208	5.959
7	0.263	0.711	1.415	1.895	2.365	2.998	3.499	4.019	4.785	5.408
8	0.262	0.708	1.397	1.860	2.308	2.898	3.355	3.833	4.501	5.041
9	0.261	0.703	1.383	1.833	2.282	2.821	3.250	3.690	4.297	4.781
10	0.260	0.700	1.372	1.812	2.228	2.784	3.169	3.581	4.144	4.587
11	0.260	0.697	1.363	1.798	2.201	2.718	3.106	3.497	4.025	4.437
12	0.259	0.695	1.358	1.782	2.179	2.681	3.055	3.428	3.930	4.318
13	0.259	0.694	1.350	1.771	2.160	2.650	3.012	3.372	3.852	4.221
14	0.258	0.692	1.345	1.761	2.145	2.624	2.977	3.326	3.787	4.140
15	0.258	0.691	1.341	1.753	2.131	2.602	2.947	3.286	3.733	4.073
16	0.258	0.690	1.337	1.748	2.120	2.583	2.921	3.252	3.686	4.015
17	0.257	0.689	1.333	1.740	2.110	2.567	2.898	3.222	3.646	3.965
18	0.257	0.688	1.330	1.734	2.101	2.552	2.878	3.197	3.610	3.922
19	0.257	0.688	1.328	1.729	2.093	2.539	2.861	3.174	3.579	3.883
20	0.257	0.687	1.325	1.725	2.086	2.526	2.845	3.153	3.552	3.850
21	0.257	0.686	1.323	1.721	2.080	2.518	2.831	3.135	3.527	3.819
22	0.256	0.686	1.321	1.717	2.074	2.508	2.819	3.119	3.505	3.792
23	0.256	0.685	1.319	1.714	2.069	2.500	2.807	3.104	3.485	3.767
24	0.256	0.685	1.318	1.711	2.064	2.492	2.797	3.091	3.467	3.745
25	0.256	0.684	1.318	1.708	2.060	2.485	2.787	3.078	3.450	3.725
26	0.256	0.684	1.315	1.706	2.056	2.479	2.779	3.057	3.435	3.707
27	0.256	0.684	1.314	1.703	2.052	2.473	2.771	3.057	3.421	3.690
28	0.256	0.683	1.313	1.701	2.048	2.467	2.763	3.047	3.408	3.674
29	0.256	0.683	1.311	1.699	2.045	2.462	2.756	3.038	3.396	3.659
30	0.256	0.683	1.310	1.697	2.042	2.457	2.750	3.030	3.385	3.646
40	0.256	0.681	1.303	1.684	2.021	2.423	2.704	2.971	3.307	3.651
60	0.254	0.679	1.298	1.671	2.000	2.390	2.660	2.915	3.232	3.480
120	0.254	0.677	1.289	1.658	1.980	2.358	2.617	2.860	3.160	3.373
∞	0.253	0.674	1.282	1.645	1.960	2.326	2.576	2.807	3.090	3.291

 df = degrees of freedom* Adapted with permission from *Biometrika Tables for Statisticians*, Vol. 1, 3rd edition by E. S. Pearson and H. O. Hartley, Cambridge University Press, Cambridge, 1968.

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จุฬาลงกรณ์มหาวิทยาลัย

Appendix C : Experimental Data

Material	Amplitude	Part	Cutting Edge	Edge Seal	Inner Length	Inner Width	T,%sh L ,	T,%shW,
70	70	1	0.118	0.397	19.234	5.190	1.9830	4.7366
70	70	2	0.118	0.397	19.234	5.190	1.8252	6.5558
70	70	3	0.118	0.397	19.234	5.190	1.9093	5.5309
70	70	4	0.118	0.397	19.234	5.190	2.1623	4.3725
70	70	5	0.118	0.397	19.234	5.190	1.8042	5.9621
70	70	6	0.118	0.397	19.234	5.190	2.0937	6.1001
70	70	7	0.118	0.397	19.234	5.190	1.9566	4.5638
70	70	8	0.118	0.397	19.234	5.190	1.7780	5.8638
70	70	9	0.118	0.397	19.234	5.190	1.7046	6.0409
70	70	10	0.118	0.397	19.234	5.190	1.8357	5.8442
70	80	1	0.118	0.397	19.234	5.190	2.0884	5.9621
70	80	2	0.118	0.397	19.234	5.190	2.1095	6.2186
70	80	3	0.118	0.397	19.234	5.190	1.8462	5.2777
70	80	4	0.118	0.397	19.234	5.190	2.1095	5.6677
70	80	5	0.118	0.397	19.234	5.190	1.8830	5.7657
70	80	6	0.118	0.397	19.234	5.190	2.0831	7.3983
70	80	7	0.118	0.397	19.234	5.190	2.1518	5.7069
70	80	8	0.118	0.397	19.234	5.190	2.0198	6.2186
70	80	9	0.118	0.397	19.234	5.190	1.8777	6.3770
70	80	10	0.118	0.397	19.234	5.190	2.0831	6.8552
70	90	1	0.118	0.397	19.234	5.190	2.2787	8.4601
70	90	2	0.118	0.397	19.234	5.190	2.1570	5.7853
70	90	3	0.118	0.397	19.234	5.190	2.2893	6.0606
70	90	4	0.118	0.397	19.234	5.190	2.0673	7.0959
70	90	5	0.118	0.397	19.234	5.190	2.0304	5.3555
70	90	6	0.118	0.397	19.234	5.190	2.1042	5.7461
70	90	7	0.118	0.397	19.234	5.190	2.0409	5.4334
70	90	8	0.118	0.397	19.234	5.190	2.2470	5.5895
70	90	9	0.118	0.397	19.234	5.190	1.9830	6.8953
70	90	10	0.118	0.397	19.234	5.190	2.0040	5.6873
70	100	1	0.118	0.397	19.234	5.190	2.2258	4.4298
70	100	2	0.118	0.397	19.234	5.190	2.1518	6.6555
70	100	3	0.118	0.397	19.234	5.190	2.1835	5.1613
70	100	4	0.118	0.397	19.234	5.190	2.2099	7.0758
70	100	5	0.118	0.397	19.234	5.190	2.1729	5.2195
70	100	6	0.118	0.397	19.234	5.190	2.2417	5.6090
70	100	7	0.118	0.397	19.234	5.190	2.0462	6.6953
70	100	8	0.118	0.397	19.234	5.190	1.9988	6.7353
70	100	9	0.118	0.397	19.234	5.190	1.9619	6.4564
70	100	10	0.118	0.397	19.234	5.190	2.1571	5.4139
100	70	1	0.118	0.397	19.234	5.190	2.2258	3.7650
100	70	2	0.118	0.397	19.234	5.190	2.0146	4.2962
100	70	3	0.118	0.397	19.234	5.190	1.9514	3.8406
100	70	4	0.118	0.397	19.234	5.190	2.1993	3.2392
100	70	5	0.118	0.397	19.234	5.190	2.0409	3.8406
100	70	6	0.118	0.397	19.234	5.190	2.2205	4.3152
100	70	7	0.118	0.397	19.234	5.190	1.9672	4.0299
100	70	8	0.118	0.397	19.234	5.190	2.2470	5.2583
100	70	9	0.118	0.397	19.234	5.190	2.2946	3.7461
100	70	10	0.118	0.397	19.234	5.190	1.9830	4.0299
100	80	1	0.118	0.397	19.234	5.190	2.2258	4.8713
100	80	2	0.118	0.397	19.234	5.190	2.1835	4.4298
100	80	3	0.118	0.397	19.234	5.190	2.0567	5.6677
100	80	4	0.118	0.397	19.234	5.190	2.2999	4.3534
100	80	5	0.118	0.397	19.234	5.190	2.2787	4.6405
100	80	6	0.118	0.397	19.234	5.190	2.1623	4.2390
100	80	7	0.118	0.397	19.234	5.190	2.2734	4.5255
100	80	8	0.118	0.397	19.234	5.190	2.4166	4.1819

Appendix C : Experimental Data (Cont.)

Material	Amplitude	Part	Cutting Edge	Edge Seal	Inner Length	Inner Width	T,%sh L,	T,%shW,
100	80	9	0.118	0.397	19.234	5.190	2.0304	5.2583
100	80	10	0.118	0.397	19.234	5.190	2.2681	4.3725
100	90	1	0.118	0.397	19.234	5.190	2.0673	4.6405
100	90	2	0.118	0.397	19.234	5.190	2.3211	5.1225
100	90	3	0.118	0.397	19.234	5.190	2.2681	4.6981
100	90	4	0.118	0.397	19.234	5.190	2.1941	4.7750
100	90	5	0.118	0.397	19.234	5.190	2.2311	5.4334
100	90	6	0.118	0.397	19.234	5.190	2.2364	4.9292
100	90	7	0.118	0.397	19.234	5.190	2.3689	4.7943
100	90	8	0.118	0.397	19.234	5.190	2.4007	4.5063
100	90	9	0.118	0.397	19.234	5.190	2.2046	5.8049
100	90	10	0.118	0.397	19.234	5.190	2.3954	4.3343
100	100	1	0.118	0.397	19.234	5.190	2.6135	5.7657
100	100	2	0.118	0.397	19.234	5.190	2.4911	4.5830
100	100	3	0.118	0.397	19.234	5.190	2.5336	5.2389
100	100	4	0.118	0.397	19.234	5.190	2.3052	5.3360
100	100	5	0.118	0.397	19.234	5.190	2.2840	5.6090
100	100	6	0.118	0.397	19.234	5.190	2.3848	5.8245
100	100	7	0.118	0.397	19.234	5.190	2.3211	5.7265
100	100	8	0.118	0.397	19.234	5.190	2.3370	5.0451
100	100	9	0.118	0.397	19.234	5.190	2.4645	5.4529
100	100	10	0.118	0.397	19.234	5.190	2.2893	5.0838
70	70	1	1.9812	1.2141	20.785	10.780	2.1532	2.4581
70	70	2	1.9812	1.2141	20.785	10.780	1.9546	2.6493
70	70	3	1.9812	1.2141	20.785	10.780	1.7898	2.7067
70	70	4	1.9812	1.2141	20.785	10.780	2.1422	2.4772
70	70	5	1.9812	1.2141	20.785	10.780	2.3082	2.7259
70	70	6	1.9812	1.2141	20.785	10.780	2.3415	3.3239
70	70	7	1.9812	1.2141	20.785	10.780	2.1864	2.5154
70	70	8	1.9812	1.2141	20.785	10.780	2.2196	2.8219
70	70	9	1.9812	1.2141	20.785	10.780	2.0318	3.1690
70	70	10	1.9812	1.2141	20.785	10.780	1.9326	3.0723
70	80	1	1.9812	1.2141	20.785	10.780	2.5193	2.9181
70	80	2	1.9812	1.2141	20.785	10.780	1.9216	2.8796
70	80	3	1.9812	1.2141	20.785	10.780	1.8666	3.0723
70	80	4	1.9812	1.2141	20.785	10.780	2.0980	2.7067
70	80	5	1.9812	1.2141	20.785	10.780	2.1753	2.8219
70	80	6	1.9812	1.2141	20.785	10.780	1.8886	2.8219
70	80	7	1.9812	1.2141	20.785	10.780	2.1753	2.2487
70	80	8	1.9812	1.2141	20.785	10.780	2.3526	2.3247
70	80	9	1.9812	1.2141	20.785	10.780	2.0869	3.2658
70	80	10	1.9812	1.2141	20.785	10.780	1.9106	2.6684
70	90	1	1.9812	1.2141	20.785	10.780	2.1201	2.8411
70	90	2	1.9812	1.2141	20.785	10.780	2.2196	2.4772
70	90	3	1.9812	1.2141	20.785	10.780	2.2860	2.4963
70	90	4	1.9812	1.2141	20.785	10.780	2.0208	2.7067
70	90	5	1.9812	1.2141	20.785	10.780	2.3193	3.4600
70	90	6	1.9812	1.2141	20.785	10.780	2.1975	3.0530
70	90	7	1.9812	1.2141	20.785	10.780	2.1201	3.0530
70	90	8	1.9812	1.2141	20.785	10.780	2.4081	2.6876
70	90	9	1.9812	1.2141	20.785	10.780	2.2749	3.2270
70	90	10	1.9812	1.2141	20.785	10.780	2.3193	3.0530
70	100	1	1.9812	1.2141	20.785	10.780	2.3193	2.9181
70	100	2	1.9812	1.2141	20.785	10.780	2.1864	3.0144
70	100	3	1.9812	1.2141	20.785	10.780	1.9767	2.7259
70	100	4	1.9812	1.2141	20.785	10.780	2.1753	2.9566
70	100	5	1.9812	1.2141	20.785	10.780	1.7678	2.6301
70	100	6	1.9812	1.2141	20.785	10.780	1.9767	2.5345

Appendix C : Experimental Data (Cont.)

Material	Amplitude	Part	Cutting Edge	Edge Seal	Inner Length	Inner Width	T,%sh L ,	T%shW,
70	100	7	1.9812	1.2141	20.785	10.780	2.1422	2.7835
70	100	8	1.9812	1.2141	20.785	10.780	2.3526	2.9951
70	100	9	1.9812	1.2141	20.785	10.780	2.6419	2.4200
70	100	10	1.9812	1.2141	20.785	10.780	2.2196	2.4772
100	70	1	1.9812	1.2141	20.785	10.780	1.9546	2.7067
100	70	2	1.9812	1.2141	20.785	10.780	2.0980	3.0337
100	70	3	1.9812	1.2141	20.785	10.780	2.2306	3.1690
100	70	4	1.9812	1.2141	20.785	10.780	1.9106	2.7643
100	70	5	1.9812	1.2141	20.785	10.780	2.0318	3.4016
100	70	6	1.9812	1.2141	20.785	10.780	1.7568	2.7643
100	70	7	1.9812	1.2141	20.785	10.780	1.9767	2.7835
100	70	8	1.9812	1.2141	20.785	10.780	1.5052	3.4211
100	70	9	1.9812	1.2141	20.785	10.780	1.8776	2.2297
100	70	10	1.9812	1.2141	20.785	10.780	1.9216	2.4963
100	80	1	1.9812	1.2141	20.785	10.780	2.1311	3.3434
100	80	2	1.9812	1.2141	20.785	10.780	2.6084	3.4600
100	80	3	1.9812	1.2141	20.785	10.780	2.3637	3.1303
100	80	4	1.9812	1.2141	20.785	10.780	2.0428	3.6744
100	80	5	1.9812	1.2141	20.785	10.780	2.2306	3.5573
100	80	6	1.9812	1.2141	20.785	10.780	2.4748	3.7722
100	80	7	1.9812	1.2141	20.785	10.780	2.3304	3.4600
100	80	8	1.9812	1.2141	20.785	10.780	2.1422	4.0272
100	80	9	1.9812	1.2141	20.785	10.780	2.2306	3.1109
100	80	10	1.9812	1.2141	20.785	10.780	2.2749	3.3628
100	90	1	1.9812	1.2141	20.785	10.780	2.1422	3.7917
100	90	2	1.9812	1.2141	20.785	10.780	2.0318	3.7917
100	90	3	1.9812	1.2141	20.785	10.780	2.6307	3.6353
100	90	4	1.9812	1.2141	20.785	10.780	1.9877	2.9759
100	90	5	1.9812	1.2141	20.785	10.780	2.1753	3.8113
100	90	6	1.9812	1.2141	20.785	10.780	1.8776	2.9759
100	90	7	1.9812	1.2141	20.785	10.780	2.1090	3.3628
100	90	8	1.9812	1.2141	20.785	10.780	1.9216	3.1883
100	90	9	1.9812	1.2141	20.785	10.780	1.9216	3.5963
100	90	10	1.9812	1.2141	20.785	10.780	1.7898	3.2658
100	100	1	1.9812	1.2141	20.785	10.780	2.4636	2.5536
100	100	2	1.9812	1.2141	20.785	10.780	2.1201	2.9373
100	100	3	1.9812	1.2141	20.785	10.780	2.1422	3.6939
100	100	4	1.9812	1.2141	20.785	10.780	2.4748	3.2852
100	100	5	1.9812	1.2141	20.785	10.780	2.0318	3.4211
100	100	6	1.9812	1.2141	20.785	10.780	1.9546	3.7722
100	100	7	1.9812	1.2141	20.785	10.780	2.3193	3.3434
100	100	8	1.9812	1.2141	20.785	10.780	2.0097	2.4581
100	100	9	1.9812	1.2141	20.785	10.780	1.8117	3.7526
100	100	10	1.9812	1.2141	20.785	10.780	2.6084	3.4989
70	70	1	0.096	0.165	7.918	7.912	1.8175	3.8633
70	70	2	0.096	0.165	7.918	7.912	1.7415	2.6243
70	70	3	0.096	0.165	7.918	7.912	1.6277	3.6394
70	70	4	0.096	0.165	7.918	7.912	3.0620	3.0903
70	70	5	0.096	0.165	7.918	7.912	2.0971	3.3641
70	70	6	0.096	0.165	7.918	7.912	2.5066	3.1033
70	70	7	0.096	0.165	7.918	7.912	1.6025	3.4819
70	70	8	0.096	0.165	7.918	7.912	1.9571	2.9345
70	70	9	0.096	0.165	7.918	7.912	1.3758	3.3118
70	70	10	0.096	0.165	7.918	7.912	1.6025	3.7973
70	80	1	0.096	0.165	7.918	7.912	2.3142	4.3539
70	80	2	0.096	0.165	7.918	7.912	1.5394	2.7663
70	80	3	0.096	0.165	7.918	7.912	1.5268	3.2075
70	80	4	0.096	0.165	7.918	7.912	1.0663	3.3003

Appendix C : Experimental Data (Cont.)

Material	Amplitude	Part	Cutting Edge	Edge Seal	Inner Length	Inner Width	T,%sh L ,	T%shW,
70	80	5	0.096	0.165	7.918	7.912	1.4009	3.4295
70	80	6	0.096	0.165	7.918	7.912	1.5142	3.0383
70	80	7	0.096	0.165	7.918	7.912	1.5016	2.9475
70	80	8	0.096	0.165	7.918	7.912	1.8302	2.5599
70	80	9	0.096	0.165	7.918	7.912	1.9190	2.9086
70	80	10	0.096	0.165	7.918	7.912	1.9571	3.7051
70	90	1	0.096	0.165	7.918	7.912	2.9323	4.1279
70	90	2	0.096	0.165	7.918	7.912	2.7513	2.7792
70	90	3	0.096	0.165	7.918	7.912	1.9063	3.3641
70	90	4	0.096	0.165	7.918	7.912	2.4167	3.0773
70	90	5	0.096	0.165	7.918	7.912	2.5066	3.9425
70	90	6	0.096	0.165	7.918	7.912	2.1481	4.3273
70	90	7	0.096	0.165	7.918	7.912	2.2759	3.8633
70	90	8	0.096	0.165	7.918	7.912	1.5773	3.9822
70	90	9	0.096	0.165	7.918	7.912	2.8029	3.4688
70	90	10	0.096	0.165	7.918	7.912	2.1736	4.1147
70	100	1	0.096	0.165	7.918	7.912	2.7255	3.7973
70	100	2	0.096	0.165	7.918	7.912	2.9453	3.7841
70	100	3	0.096	0.165	7.918	7.912	3.9263	3.9161
70	100	4	0.096	0.165	7.918	7.912	1.6783	3.9557
70	100	5	0.096	0.165	7.918	7.912	3.1140	3.7578
70	100	6	0.096	0.165	7.918	7.912	2.6481	3.3772
70	100	7	0.096	0.165	7.918	7.912	2.1992	4.1279
70	100	8	0.096	0.165	7.918	7.912	2.4039	4.1412
70	100	9	0.096	0.165	7.918	7.912	2.0334	4.1943
70	100	10	0.096	0.165	7.918	7.912	3.1920	3.7841
100	70	1	0.096	0.165	7.918	7.912	2.4296	3.2857
100	70	2	0.096	0.165	7.918	7.912	2.3911	4.0484
100	70	3	0.096	0.165	7.918	7.912	2.2120	3.3118
100	70	4	0.096	0.165	7.918	7.912	3.5579	3.9425
100	70	5	0.096	0.165	7.918	7.912	2.6095	3.8237
100	70	6	0.096	0.165	7.918	7.912	2.8935	3.8369
100	70	7	0.096	0.165	7.918	7.912	4.5774	4.8627
100	70	8	0.096	0.165	7.918	7.912	2.6610	3.9425
100	70	9	0.096	0.165	7.918	7.912	2.3014	3.9029
100	70	10	0.096	0.165	7.918	7.912	3.3354	4.6881
100	80	1	0.096	0.165	7.918	7.912	2.0971	3.8105
100	80	2	0.096	0.165	7.918	7.912	2.4039	3.3118
100	80	3	0.096	0.165	7.918	7.912	2.7900	3.9690
100	80	4	0.096	0.165	7.918	7.912	3.3224	3.4688
100	80	5	0.096	0.165	7.918	7.912	3.1140	4.0881
100	80	6	0.096	0.165	7.918	7.912	2.0462	3.7314
100	80	7	0.096	0.165	7.918	7.912	2.5709	3.6131
100	80	8	0.096	0.165	7.918	7.912	2.2886	3.9557
100	80	9	0.096	0.165	7.918	7.912	3.6629	4.7015
100	80	10	0.096	0.165	7.918	7.912	2.3911	4.2076
100	90	1	0.096	0.165	7.918	7.912	3.7944	4.2076
100	90	2	0.096	0.165	7.918	7.912	2.8158	3.4819
100	90	3	0.096	0.165	7.918	7.912	3.0750	4.1810
100	90	4	0.096	0.165	7.918	7.912	3.4008	4.3939
100	90	5	0.096	0.165	7.918	7.912	2.8029	4.3140
100	90	6	0.096	0.165	7.918	7.912	3.4662	3.5081
100	90	7	0.096	0.165	7.918	7.912	1.8936	3.8633
100	90	8	0.096	0.165	7.918	7.912	3.1270	3.9690
100	90	9	0.096	0.165	7.918	7.912	3.6760	4.1412
100	90	10	0.096	0.165	7.918	7.912	2.8288	4.2076
100	100	1	0.096	0.165	7.918	7.912	2.7255	4.3406
100	100	2	0.096	0.165	7.918	7.912	3.3224	3.5737

Appendix C : Experimental Data (Cont.)

Material	Amplitude	Part	Cutting Edge	Edge Seal	Inner Length	Inner Width	T,%sh L ,	T%shW,
100	100	3	0.096	0.165	7.918	7.912	2.5966	4.5007
100	100	4	0.096	0.165	7.918	7.912	2.6352	4.0881
100	100	5	0.096	0.165	7.918	7.912	2.5709	3.9822
100	100	6	0.096	0.165	7.918	7.912	3.1790	3.6394
100	100	7	0.096	0.165	7.918	7.912	2.3783	4.2076
100	100	8	0.096	0.165	7.918	7.912	3.5579	3.5868
100	100	9	0.096	0.165	7.918	7.912	3.1270	4.5007
100	100	10	0.096	0.165	7.918	7.912	2.5709	3.5737

240

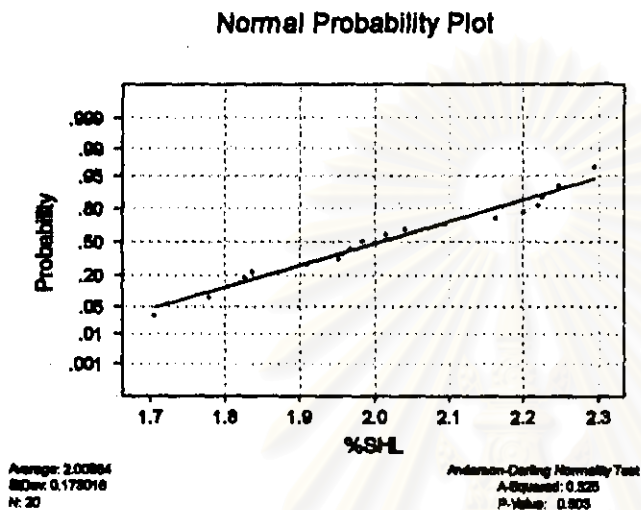


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Appendix D : Result of ANOVA Test

- Result ANOVA on Material's Effect**

Condition # 1 : Evaluate effect of materials on %SHL @ A70, D1



One-Way Analysis of Variance

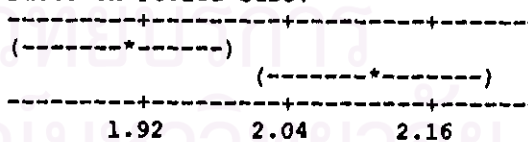
Analysis of Variance for %SHL

Source	DF	SS	MS	F	P
M	1	0.2187	0.2187	11.25	0.004
Error	18	0.3500	0.0194		
Total	19	0.5688			

Level	N	Mean	StDev
70	10	1.9053	0.1446
100	10	2.1144	0.1341

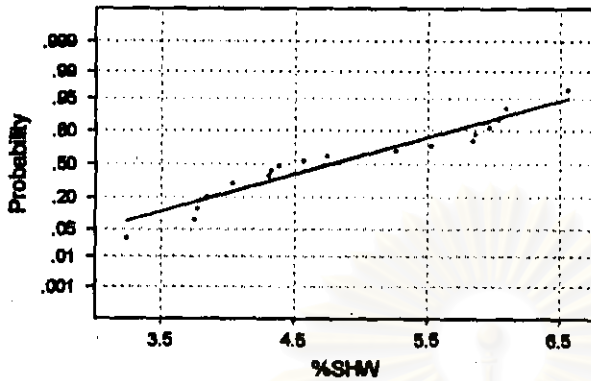
Pooled StDev = 0.1394

Individual 95% CIs For Mean
Based on Pooled StDev



Condition # 2 : Evaluate effect of materials on %SHW @ A70, D1

Normal Probability Plot



Average: 4.79839
 StDev: 1.00016
 N: 20

Anderson-Darling Normality Test
 A-Statistic: 0.721
 P-Value: 0.680

One-Way Analysis of Variance

Analysis of Variance for %SHW

Source	DF	SS	MS	F	P
M	1	11.567	11.567	27.99	0.000
Error	18	7.439	0.413		
Total	19	19.006			

Individual 95% CIs For Mean
 Based on Pooled StDev

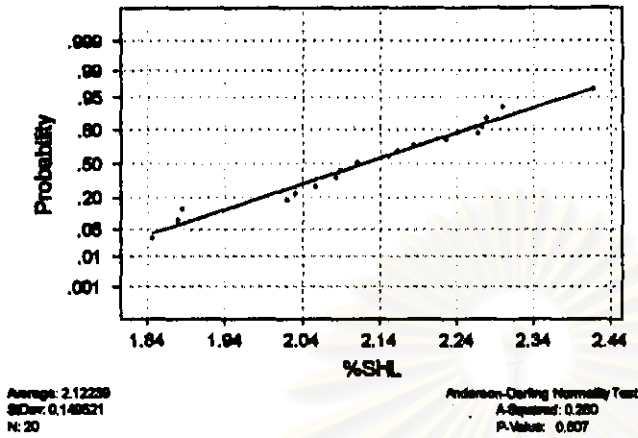
Level	N	Mean	StDev
70	10	5.5571	0.7402
100	10	4.0361	0.5279

Pooled StDev = 0.6429

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Condition # 3 : Evaluate effect of materials on %SHL @ A80, D1

Normal Probability Plot



One-Way Analysis of Variance

Analysis of Variance for %SHL

Source	DF	SS	MS	F	P
M	1	0.1888	0.1888	14.41	0.001
Error	18	0.2359	0.0131		
Total	19	0.4248			

Individual 95% CIs For Mean
Based on Pooled StDev

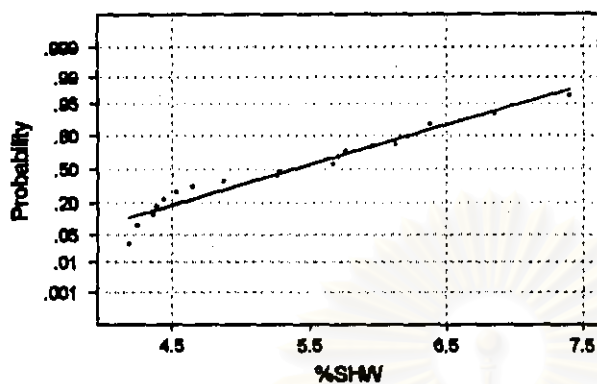
Level	N	Mean	StDev	CI Lower	CI Upper
70	10	2.0252	0.1130	1.80	2.25
100	10	2.2196	0.1159	2.00	2.44

Pooled StDev = 0.1145

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Condition # 4 : Evaluate effect of materials on %SHW @ A80, D1

Normal Probability Plot



Average: 5.58259
 StDev: 0.55775
 N: 20

Anderson-Darling Normality Test
 A-Squared: 0.424
 P-Value: 0.288

One-Way Analysis of Variance

Analysis of Variance for %SHW

Source	DF	SS	MS	F	P
M	1	11.112	11.112	35.97	0.000
Error	18	5.561	0.309		
Total	19	16.673			

Individual 95% CIs For Mean
Based on Pooled StDev

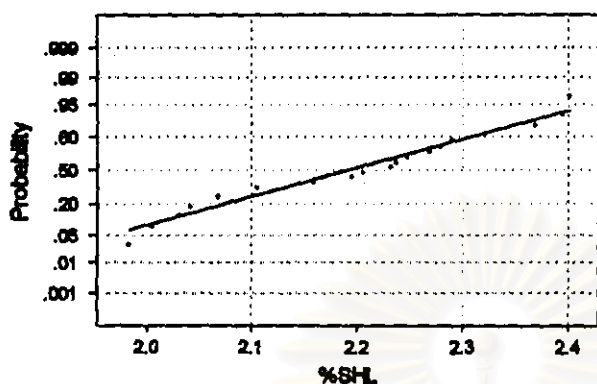
Level	N	Mean	StDev	CI Lower	CI Upper
70	10	6.1448	0.6226	4.90	6.30
100	10	4.6540	0.4798	4.90	6.30

Pooled StDev = 0.5558

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Condition # 5 : Evaluate effect of materials on %SHL @ A90, D1

Normal Probability Plot



Average: 2.19448
 StDev: 0.131836
 N: 20

Anderson-Darling Normality Test
 A-Squared: 0.363
 P-Value: 0.454



One-Way Analysis of Variance

Analysis of Variance for %SHL

Source	DF	SS	MS	F	P
M	1	0.1104	0.1104	9.04	0.008
Error	18	0.2199	0.0122		
Total	19	0.3302			

Individual 95% CIs For Mean
 Based on Pooled StDev

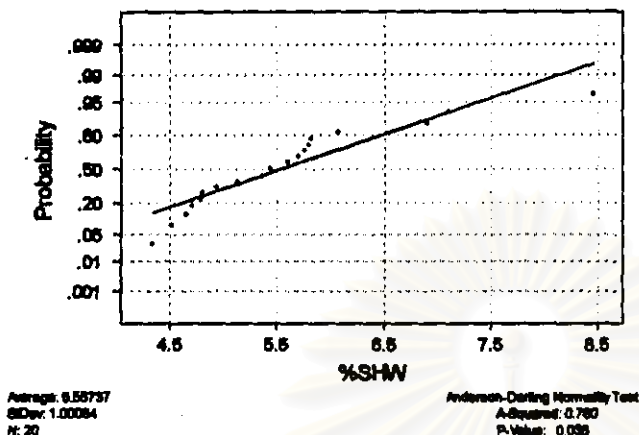
Level	N	Mean	StDev	CI Lower	CI Upper
70	10	2.1202	0.1159	2.0043	2.2361
100	10	2.2688	0.1049	2.1639	2.3737

Pooled StDev = 0.1105

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Condition # 6 : Evaluate effect of materials on %SHW @ A90, D1

Normal Probability Plot



One-Way Analysis of Variance

Analysis of Variance for %SHW

Source	DF	SS	MS	F	P
M	1	8.542	8.542	14.66	0.001
Error	18	10.490	0.583		
Total	19	19.032			

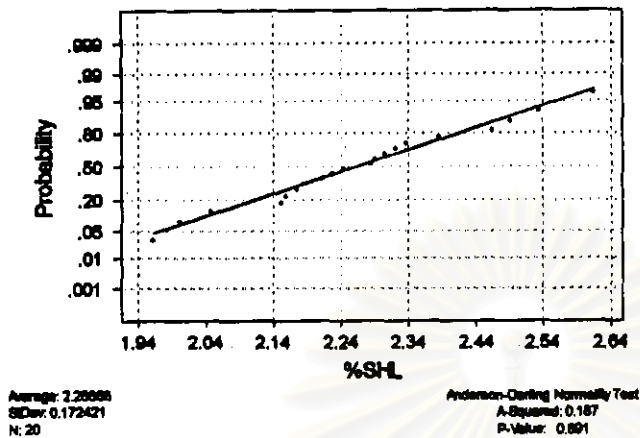
Individual 95% CIs For Mean
Based on Pooled StDev

Level	N	Mean	StDev	CI Lower	CI Upper
70	10	6.2109	0.9847	4.2262	8.1956
100	10	4.9039	0.4426	4.4613	5.3465
Pooled StDev =		0.7634		4.90	6.30

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Condition # 7 : Evaluate effect of materials on %SHL @ A100, D1

Normal Probability Plot

**One-Way Analysis of Variance**

Analysis of Variance for %SHL

Source	DF	SS	MS	F	P
M	1	0.3577	0.3577	31.09	0.000
Error	18	0.2071	0.0115		
Total	19	0.5648			

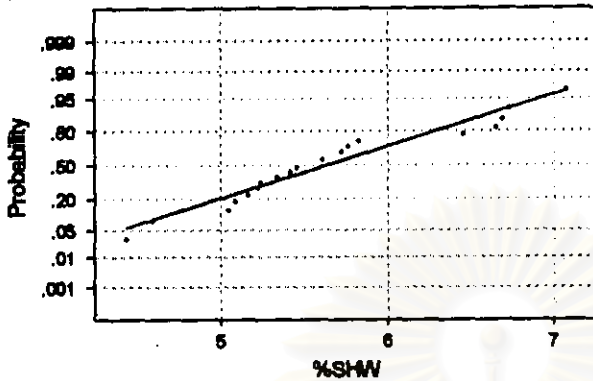
Individual 95% CIs For Mean
Based on Pooled StDev

Level	N	Mean	StDev	95% CI	
70	10	2.1349	0.0979	(-----+-----)	(-----+-----)
100	10	2.4024	0.1159	(-----+-----)	(-----+-----)
Pooled StDev =		0.1073		2.16	2.28 2.40

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Condition # 8 : Evaluate effect of materials on %SHW @ A100, D1

Normal Probability Plot



Average: 5.85566
 StDev: 0.729724
 N: 20

Anderson-Darling Normality Test
 A-Squared: 0.881
 P-Value: 0.186

One-Way Analysis of Variance

Analysis of Variance for %SHW

Source	DF	SS	MS	F	P
M	1	1.674	1.674	3.57	0.075
Error	18	8.443	0.469		
Total	19	10.117			

Individual 95% CIs For Mean
 Based on Pooled StDev

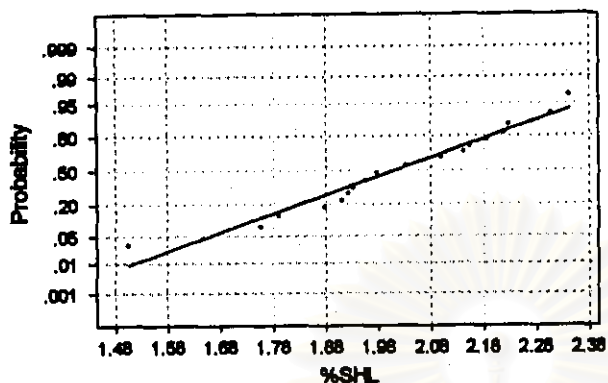
Level	N	Mean	StDev
70	10	5.9452	0.8859
100	10	5.3665	0.3915

Pooled StDev = 0.6849

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Condition # 9 : Evaluate effect of materials on %SHL @ A70, D2

Normal Probability Plot



Average: 2.01617
 StDev: 0.203165
 N: 20

Anderson-Darling Normality Test
 A-Square: 0.239
 P-Value: 0.747

One-Way Analysis of Variance

Analysis of Variance for %SHL

Source	DF	SS	MS	F	P
M	1	0.1613	0.1613	4.66	0.045
Error	18	0.6229	0.0346		
Total	19	0.7842			

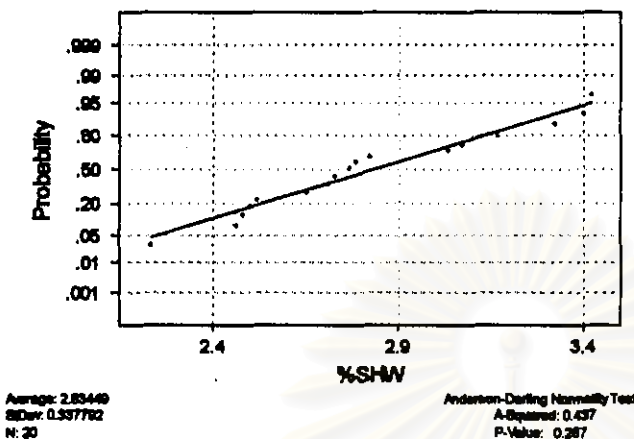
Individual 95% CIs For Mean
Based on Pooled StDev

Level	N	Mean	StDev	95% CI		
70	10	2.1060	0.1757	(-----+-----)		
100	10	1.9264	0.1959	(------+-----)		
Pooled StDev = 0.1860				1.92	2.04	2.16

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Condition # 10 : Evaluate effect of materials on %SHW @ A70, D2

Normal Probability Plot



One-Way Analysis of Variance

Analysis of Variance for %SHW

Source	DF	SS	MS	F	P
M	1	0.036	0.036	0.31	0.587
Error	18	2.132	0.118		
Total	19	2.168			

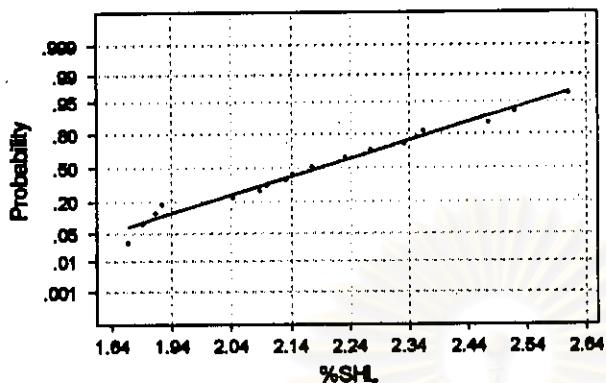
Individual 95% CIs For Mean
Based on Pooled StDev

Level	N	Mean	StDev	CI Lower	CI Upper
70	10	2.7920	0.3025	2.4895	3.0945
100	10	2.8770	0.3812	2.4958	3.2582

Pooled StDev = 0.3441

Condition # 11 : Evaluate effect of materials on %SHL @ A80, D2

Normal Probability Plot



Average: 2.19122
StDev: 0.210764
N: 20

Anderson-Darling Normality Test
A-Squared: 0.198
P-Value: 0.888

One-Way Analysis of Variance

Analysis of Variance for %SHL

Source	DF	SS	MS	F	P
M	1	0.1683	0.1683	4.48	0.048
Error	18	0.6755	0.0375		
Total	19	0.8438			

Individual 95% CIs For Mean
Based on Pooled StDev

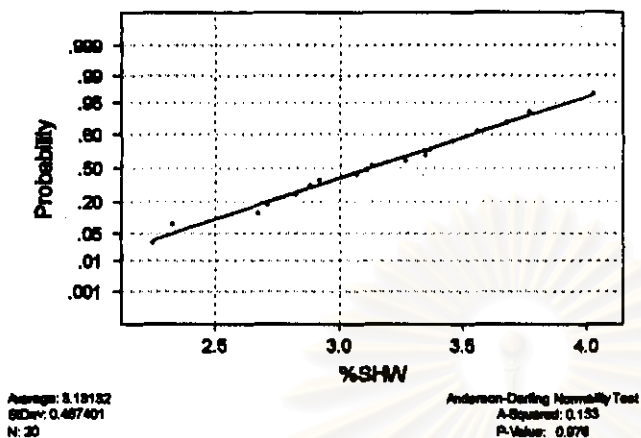
Level	N	Mean	StDev
70	10	2.0995	0.2155
100	10	2.2830	0.1692

Pooled StDev = 0.1937

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Condition # 12 : Evaluate effect of materials on %SHW @ A80, D2

Normal Probability Plot



One-Way Analysis of Variance

Analysis of Variance for %SHW

Source	DF	SS	MS	F	P
M	1	2.5706	2.5706	29.28	0.000
Error	18	1.5802	0.0878		
Total	19	4.1508			

Individual 95% CIs For Mean
Based on Pooled StDev

Level	N	Mean	StDev	CI Lower	CI Upper
70	10	2.7728	0.3093	(---*---)	(---*---)
100	10	3.4898	0.2827	(---*---)	(---*---)

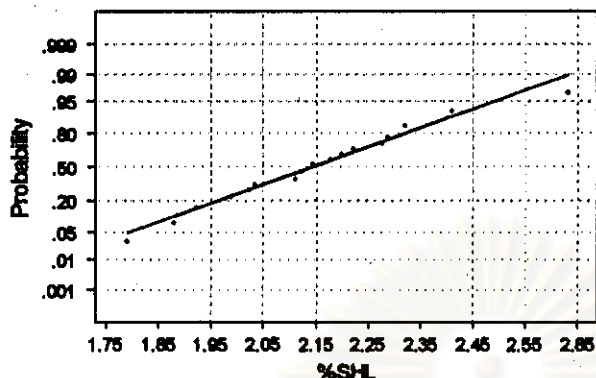
Pooled StDev = 0.2963

2.80 3.15 3.50

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Condition # 13 : Evaluate effect of materials on %SHL @ A90, D2

Normal Probability Plot



Average: 2.14384
 StDev: 0.200841
 N: 20

Anderson-Darling Normality Test
 A-Squared: 0.198
 P-Value: 0.927

One-Way Analysis of Variance

Analysis of Variance for %SHL

Source	DF	SS	MS	F	P
M	1	0.1442	0.1442	4.18	0.056
Error	18	0.6207	0.0345		
Total	19	0.7649			

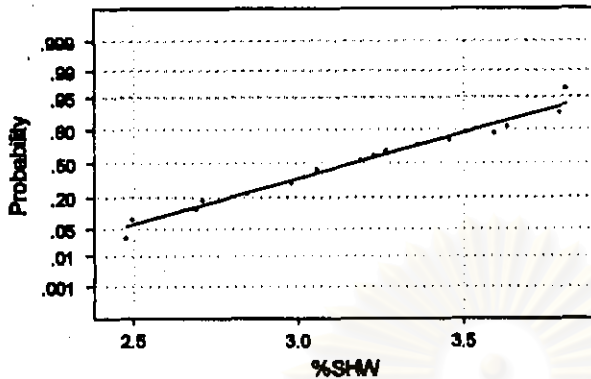
Individual 95% CIs For Mean
 Based on Pooled StDev

Level	N	Mean	StDev	-----+-----+-----		
70	10	2.2285	0.1164		(-----*-----)	
100	10	2.0587	0.2354	(-----*-----)		
Pooled StDev = 0.1857				2.04	2.16	2.28

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Condition # 14 : Evaluate effect of materials on %SHW @ A90, D2

Normal Probability Plot



Average: 3.17249
 StDev: 0.418167
 N: 20

Anderson-Darling Normality Test
 A-Squared: 0.280
 P-Value: 0.673

One-Way Analysis of Variance

Analysis of Variance for %SHW

Source	DF	SS	MS	F	P
M	1	1.426	1.426	13.53	0.002
Error	18	1.897	0.105		
Total	19	3.322			

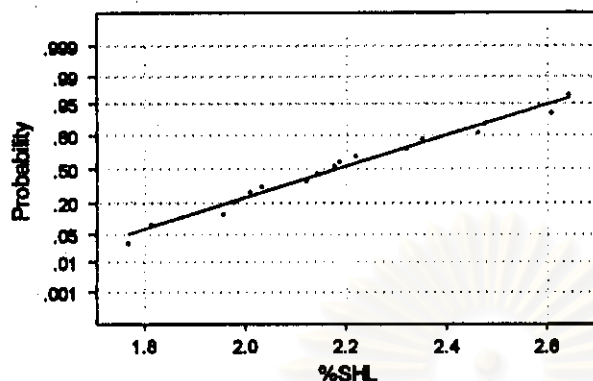
Individual 95% CIs For Mean
Based on Pooled StDev

Level	N	Mean	StDev	95% CI	
70	10	2.9055	0.3194	(2.58, 3.23)	
100	10	3.4395	0.3297		(3.11, 3.77)
Pooled StDev =		0.3246		2.70	3.00

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Condition # 15 : Evaluate effect of materials on %SHL @ A100, D2

Normal Probability Plot



Average: 2.18472
 StDev: 0.243918
 N: 20

Anderson-Darling Normality Test
 A-Squared: 0.217
 P-Value: 0.818

One-Way Analysis of Variance

Analysis of Variance for %SHL

Source	DF	SS	MS	F	P
M	1	0.0016	0.0016	0.03	0.876
Error	18	1.1288	0.0627		
Total	19	1.1304			

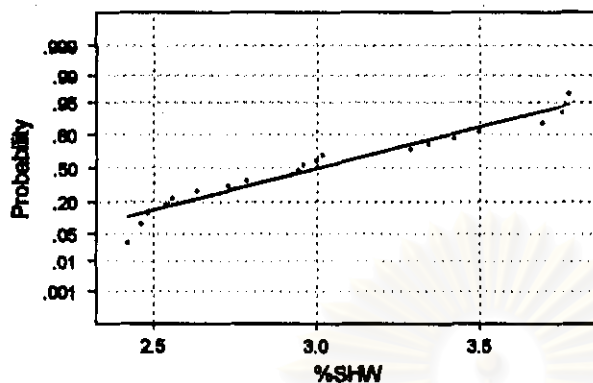
Individual 95% CIs For Mean
 Based on Pooled StDev

Level	N	Mean	StDev	CI Lower	CI Upper
70	10	2.1758	0.2399	1.9359	2.4157
100	10	2.1936	0.2605	1.9331	2.4541
Pooled StDev =		0.2504		2.10	2.30

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Condition # 16 : Evaluate effect of materials on %SHW @ A100, D2

Normal Probability Plot



Average: 3.02857
 StDev: 0.480877
 N: 20

Anderson-Darling Normality Test
 A-Squared: 0.493
 P-Value: 0.204

One-Way Analysis of Variance

Analysis of Variance for %SHW

Source	DF	SS	MS	F	P
M	1	1.384	1.384	10.06	0.005
Error	18	2.475	0.138		
Total	19	3.859			

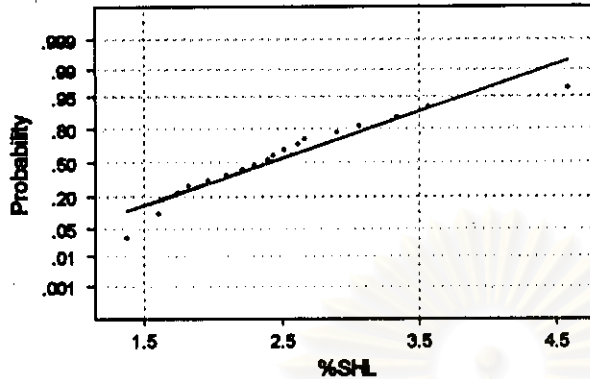
Individual 95% CIs For Mean
Based on Pooled StDev

Level	N	Mean	StDev	CI Lower	CI Upper
70	10	2.7455	0.2228	2.500	2.991
100	10	3.2716	0.4748	2.720	3.823
Pooled StDev =		0.3708		2.70	3.30

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Condition # 17 : Evaluate effect of materials on %SHL @ A70, D3

Normal Probability Plot



Average: 2.41795
 StDev: 0.797392
 N: 20

Anderson-Darling Normality Test
 A-Squared: 0.429
 P-Value: 0.280

One-Way Analysis of Variance

Analysis of Variance for %SHL

Source	DF	SS	MS	F	P
M	1	4.587	4.587	11.48	0.003
Error	18	7.193	0.400		
Total	19	11.780			

Individual 95% CIs For Mean
 Based on Pooled StDev

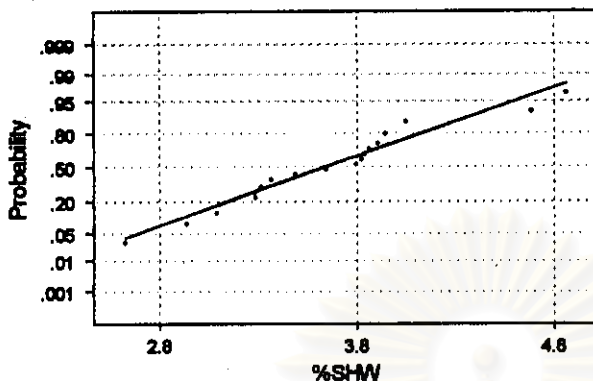
Level	N	Mean	StDev	CI Lower	CI Upper
70	10	1.9390	0.5058	0.88	2.99
100	10	2.8969	0.7371	1.38	4.41

Pooled StDev = 0.6321

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Condition # 18 : Evaluate effect of materials on %SHW @ A70, D3

Normal Probability Plot



Average: 3.64277
StDev: 0.546726
N: 20

Anderson-Darling Normality Test
A-Squared: 0.398
P-Value: 0.338

One-Way Analysis of Variance

Analysis of Variance for %SHW

Source	DF	SS	MS	F	P
M	1	2.070	2.070	10.21	0.005
Error	18	3.650	0.203		
Total	19	5.721			

Individual 95% CIs For Mean
Based on Pooled StDev

Level	N	Mean	StDev	CI
70	10	3.3210	0.3924	(-----*-----)
100	10	3.9645	0.5017	(-----*-----)

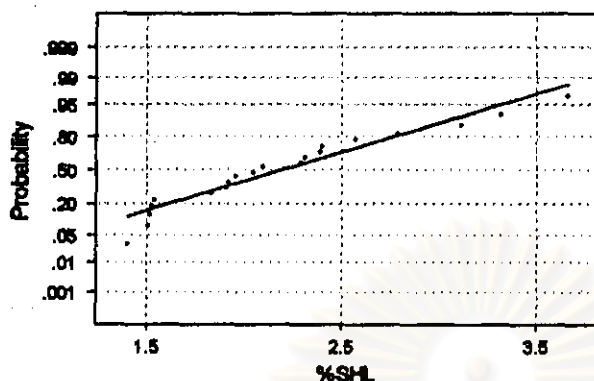
Pooled StDev = 0.4503

3.15 3.50 3.85 4.20

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Condition # 19 : Evaluate effect of materials on %SHL @ A80, D3

Normal Probability Plot



Average: 2.2084
StDev: 0.63025
N: 20

Anderson-Darling Normality Test
A-Statistic: 0.477
P-Value: 0.211

One-Way Analysis of Variance

Analysis of Variance for %SHL

Source	DF	SS	MS	F	P
M	1	4.303	4.303	22.80	0.000
Error	18	3.397	0.189		
Total	19	7.701			

Individual 95% CIs For Mean
Based on Pooled StDev

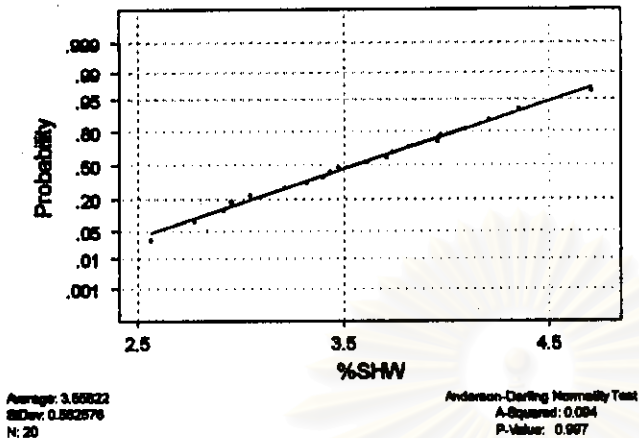
Level	N	Mean	StDev	CI Lower	CI Upper
70	10	1.7410	0.2893	1.1623	2.3197
100	10	2.6687	0.5420	1.5847	3.7527

Pooled StDev = 0.4344

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Condition # 20 : Evaluate effect of materials on %SHW @ A80, D3

Normal Probability Plot



One-Way Analysis of Variance

Analysis of Variance for %SHW

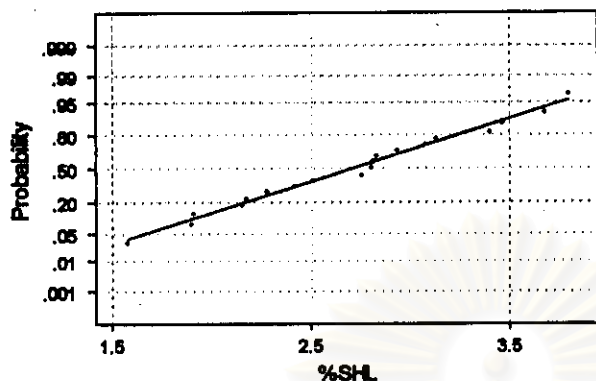
Source	DF	SS	MS	F	P
M	1	2.146	2.146	9.99	0.005
Error	18	3.868	0.215		
Total	19	6.013			

Individual 95% CIs For Mean
Based on Pooled StDev

Level	N	Mean	StDev	CI Lower	CI Upper
70	10	3.2307	0.5206	2.15	4.31
100	10	3.8858	0.3984	3.10	4.67
Pooled StDev =		0.4635		3.15	3.85

Condition # 21 : Evaluate effect of materials on %SHL @ A90, D3

Normal Probability Plot



Average: 2.71667
StDev: 0.610067
N: 20

Anderson-Darling Normality Test
A-Statistic: 0.197
P-Value: 0.672

One-Way Analysis of Variance

Analysis of Variance for %SHL

Source	DF	SS	MS	F	P
M	1	2.730	2.730	11.32	0.003
Error	18	4.342	0.241		
Total	19	7.072			

Individual 95% CIs For Mean
Based on Pooled StDev

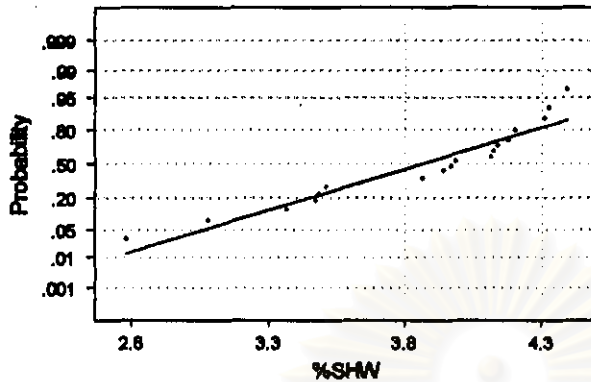
Level	N	Mean	StDev
70	10	2.3491	0.4224
100	10	3.0880	0.5514

Pooled StDev = 0.4911

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Condition # 22 : Evaluate effect of materials on %SHW @ A90, D3

Normal Probability Plot



Average: 3.8873
 StDev: 0.44428
 N: 20

Anderson-Darling Normality Test
 A-Squared: 0.628
 P-Value: 0.026

One-Way Analysis of Variance

Analysis of Variance for %SHW

Source	DF	SS	MS	F	P
M	1	0.518	0.518	2.89	0.106
Error	18	3.231	0.179		
Total	19	3.749			

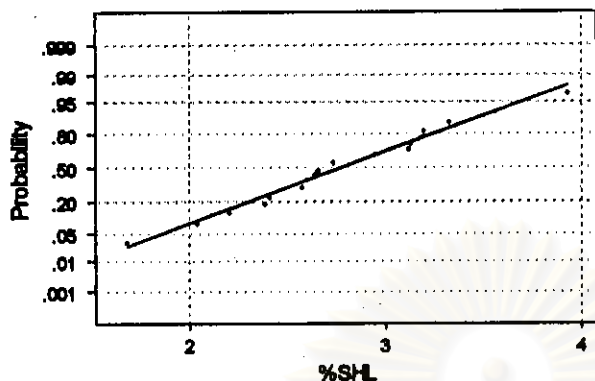
Individual 95% CIs For Mean
Based on Pooled StDev

Level	N	Mean	StDev	95% CI	
70	10	3.7047	0.5072	(-----*-----)	
100	10	4.0267	0.3189	(-----*-----)	
Pooled StDev =		0.4237		3.50	3.75 4.00 4.25

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Condition # 23 : Evaluate effect of materials on %SHL @ A100, D3

Normal Probability Plot



Average: 2.77647
 StDev: 0.532028
 N: 20

Anderson-Darling Normality Test
 A-Squared: 0.228
 P-Value: 0.780

One-Way Analysis of Variance

Analysis of Variance for %SHL

Source	DF	SS	MS	F	P
M	1	0.162	0.162	0.56	0.465
Error	18	5.216	0.290		
Total	19	5.378			

Individual 95% CIs For Mean
 Based on Pooled StDev

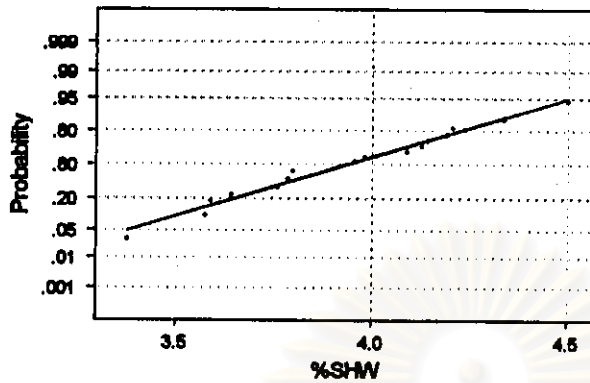
Level	N	Mean	StDev	CI Lower	CI Upper
70	10	2.6866	0.6503	1.98	3.39
100	10	2.8663	0.3959	2.45	3.28

Pooled StDev = 0.5383

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Condition # 24 : Evaluate effect of materials on %SHW @ A100, D3

Normal Probability Plot



Average: 3.94146
 StDev: 0.318887
 N: 20

Anderson-Darling Normality Test
 A-Square: 0.239
 P-Value: 0.748

One-Way Analysis of Variance

Analysis of Variance for %SHW

Source	DF	SS	MS	F	P
M	1	0.067	0.067	0.65	0.431
Error	18	1.861	0.103		
Total	19	1.928			

Individual 95% CIs For Mean
Based on Pooled StDev

Level	N	Mean	StDev	CI Lower	CI Upper
70	10	3.8836	0.2423	3.75	3.90
100	10	3.9993	0.3848	3.90	4.05

Pooled StDev = 0.3216

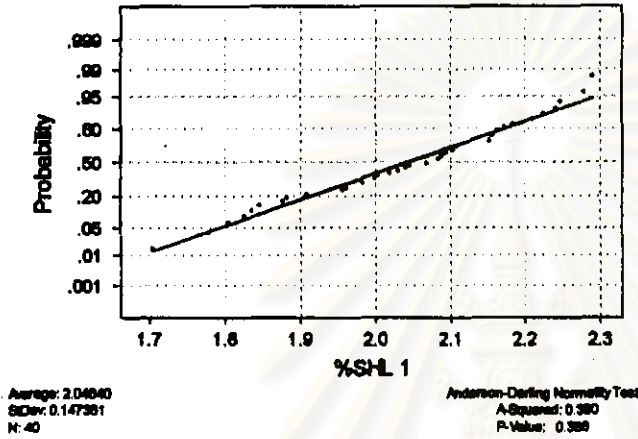
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Appendix D : Result of ANOVA Test (Cont.)

• **Result ANOVA on Amplitude's Effect**

Condition # 25 : Evaluate effect of Amp on %SHL @ M70, D1

Normal Probability Plot



One-Way Analysis of Variance

Analysis of Variance for %SHL 1

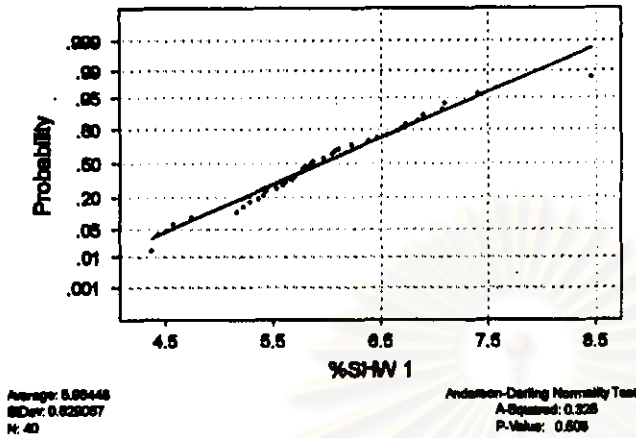
Source	DF	SS	MS	F	P
Amp	3	0.3365	0.1122	7.91	0.000
Error	36	0.5103	0.0142		
Total	39	0.8468			

Individual 95% CIs For Mean
Based on Pooled StDev

Level	N	Mean	StDev	CI Lower	CI Upper
70	10	1.9053	0.1446	1.6161	2.1945
80	10	2.0252	0.1130	1.7992	2.2512
90	10	2.1202	0.1159	1.8883	2.3521
100	10	2.1349	0.0979	2.0300	2.2398
Pooled StDev =		0.1191		1.92	2.16

Condition # 26 : Evaluate effect of Amp on %SHW @ M70, D1

Normal Probability Plot



One-Way Analysis of Variance

Analysis of Variance for %SHW 1

Source	DF	SS	MS	F	P
Amp	3	2.596	0.865	1.29	0.294
Error	36	24.211	0.673		
Total	39	26.807			

Individual 95% CIs For Mean
Based on Pooled StDev

Level	N	Mean	StDev	CI
70	10	5.5571	0.7402	(-----*-----)
80	10	6.1448	0.6226	(-----*-----)
90	10	6.2109	0.9847	(-----*-----)
100	10	5.9452	0.8859	(-----*-----)

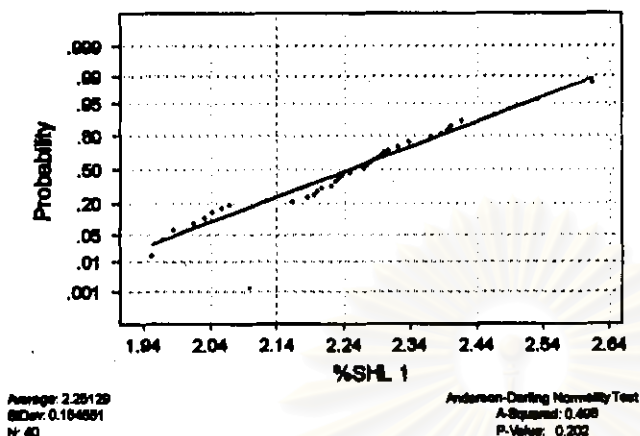
Pooled StDev = 0.8201

5.50 6.00 6.50

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Condition # 27 : Evaluate effect of Amp on %SHL @ M100, D1

Normal Probability Plot



One-Way Analysis of Variance

Analysis of Variance for %SHL 1

Source	DF	SS	MS	F	P
Amp	3	0.4289	0.1430	10.24	0.000
Error	36	0.5027	0.0140		
Total	39	0.9316			

Individual 95% CIs For Mean
Based on Pooled StDev

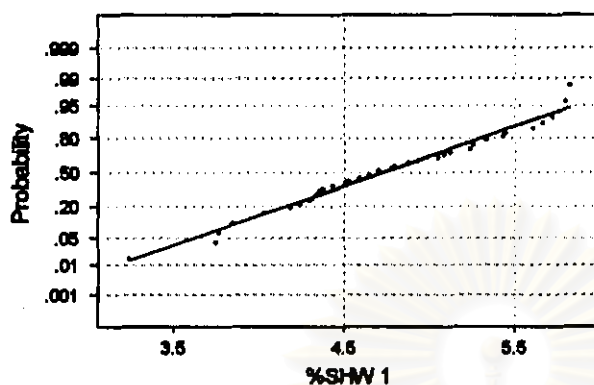
Level	N	Mean	StDev	CI Lower	CI Upper
70	10	2.1144	0.1341	1.846	2.383
80	10	2.2196	0.1159	1.988	2.451
90	10	2.2688	0.1049	2.059	2.478
100	10	2.4024	0.1159	2.171	2.634

Pooled StDev = 0.1182

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Condition # 28 : Evaluate effect of Amp on %SHW @ M100, D1

Normal Probability Plot



Average: 4.74012
 StDev: 0.463169
 N: 40

Anderson-Darling Normality Test
 A-Squared: 0.282
 P-Value: 0.620

One-Way Analysis of Variance

Analysis of Variance for %SHW 1

Source	DF	SS	MS	F	P
Amp	3	9.223	3.074	14.33	0.000
Error	36	7.723	0.215		
Total	39	16.946			

Individual 95% CIs For Mean
Based on Pooled StDev

Level	N	Mean	StDev	CI
70	10	4.0361	0.5279	(---*---)
80	10	4.6540	0.4798	(---*---)
90	10	4.9039	0.4426	(---*---)
100	10	5.3665	0.3915	(---*---)

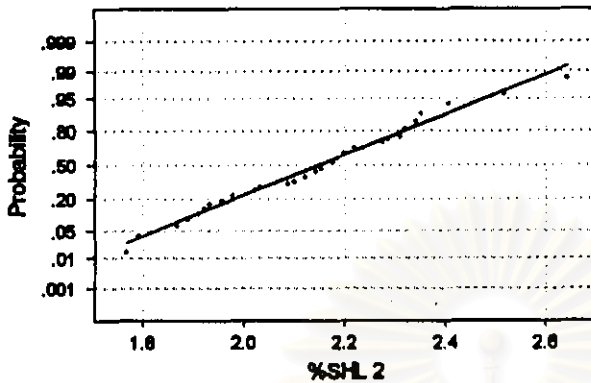
Pooled StDev = 0.4632

4.20 4.80 5.40

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Condition # 29 : Evaluate effect of Amp on %SHL @ M70, D2

Normal Probability Plot



Average: 2.16246
 StDev: 0.192723
 N: 40

Anderson-Darling Normality Test
 A-Squared: 0.301
 P-Value: 0.983

One-Way Analysis of Variance

Analysis of Variance for %SHL 2

Source	DF	SS	MS	F	P
Amp	3	0.1130	0.0377	1.02	0.397
Error	36	1.3355	0.0371		
Total	39	1.4485			

Individual 95% CIs For Mean
Based on Pooled StDev

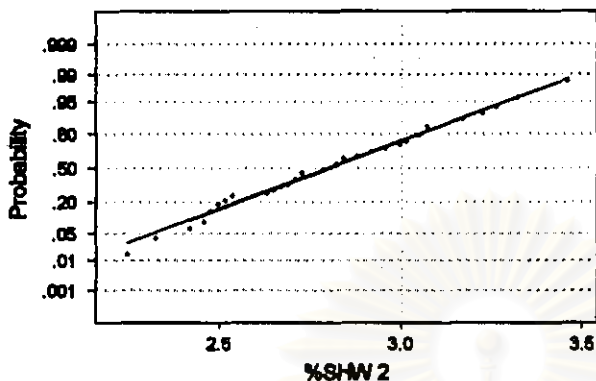
Level	N	Mean	StDev	CI Lower	CI Upper
70	10	2.1060	0.1757	1.7546	2.4574
80	10	2.0995	0.2155	1.6685	2.5305
90	10	2.2285	0.1164	2.0000	2.4570
100	10	2.1758	0.2399	1.6960	2.6556

Pooled StDev = 0.1926

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Condition # 30 : Evaluate effect of Amp on %SHW @ M70, D2

Normal Probability Plot



Average: 2.80386
 StDev: 0.286338
 N: 40

Anderson-Darling Normality Test
 A-Squared: 0.234
 P-Value: 0.782

One-Way Analysis of Variance

Analysis of Variance for %SHW 2

Source	DF	SS	MS	F	P
Amp	3	0.1484	0.0495	0.58	0.629
Error	36	3.0492	0.0847		
Total	39	3.1976			

Individual 95% CIs For Mean
 Based on Pooled StDev

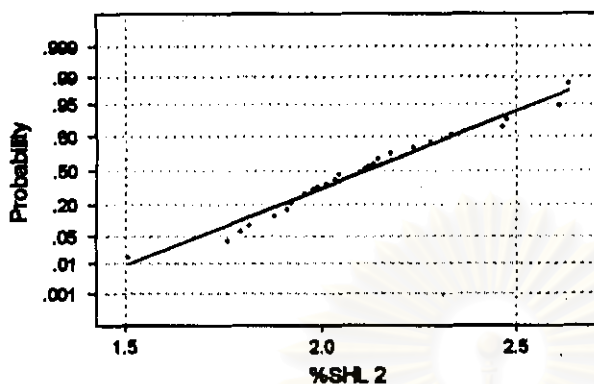
Level	N	Mean	StDev	CI
70	10	2.7920	0.3025	(-----*-----)
80	10	2.7728	0.3093	(-----*-----)
90	10	2.9055	0.3194	(-----*-----)
100	10	2.7455	0.2228	(-----*-----)

Pooled StDev = 0.2910

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Condition # 31 : Evaluate effect of Amp on %SHL @ M100, D2

Normal Probability Plot



Average: 2.11642
StDev: 0.280321
N: 40

Anderson-Darling Normality Test
A-Squared: 0.428
P-Value: 0.288

One-Way Analysis of Variance

Analysis of Variance for %SHL 2

Source	DF	SS	MS	F	P
Amp	3	0.7314	0.2438	5.13	0.005
Error	36	1.7124	0.0476		
Total	39	2.4438			

Individual 95% CIs For Mean
Based on Pooled StDev

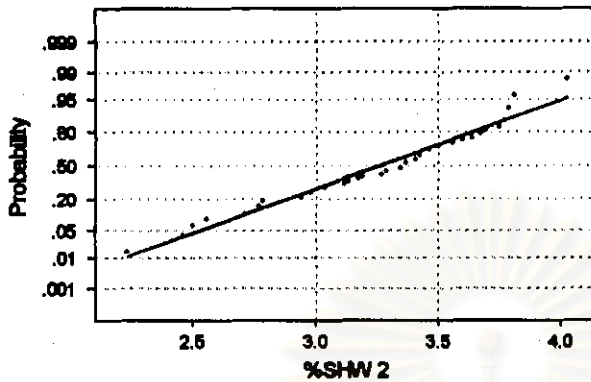
Level	N	Mean	StDev	CI Lower	CI Upper
70	10	1.9264	0.1959	1.625	2.227
80	10	2.2830	0.1692	2.014	2.552
90	10	2.0587	0.2354	1.588	2.529
100	10	2.1936	0.2605	1.673	2.714

Pooled StDev = 0.2181

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Condition # 32 : Evaluate effect of Amp on %SHW @ M100, D2

Normal Probability Plot



Average: 3.26040
 StDev: 0.434111
 N: 40

Anderson-Darling Normality Test
 A-Squared: 0.804
 P-Value: 0.160

One-Way Analysis of Variance

Analysis of Variance for %SHW 2

Source	DF	SS	MS	F	P
Amp	3	2.315	0.772	5.52	0.003
Error	36	5.035	0.140		
Total	39	7.350			

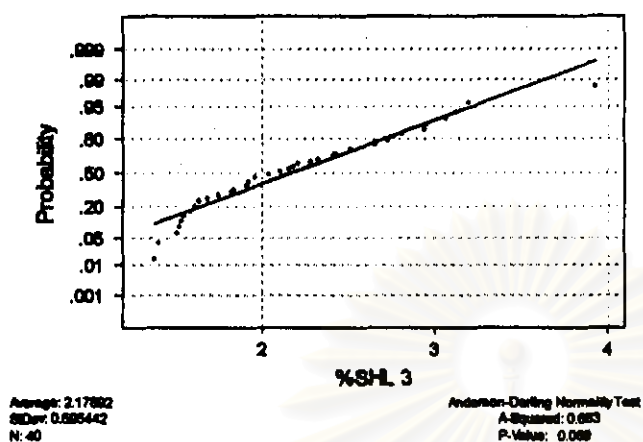
Individual 95% CIs For Mean
 Based on Pooled StDev

Level	N	Mean	StDev	CI Lower	CI Upper
70	10	2.8770	0.3812	2.4958	3.2582
80	10	3.4898	0.2827	3.2071	3.7725
90	10	3.4395	0.3297	3.1098	3.7692
100	10	3.2716	0.4748	2.7968	3.7464
Pooled StDev =		0.3740		2.70	3.60

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Condition # 33 : Evaluate effect of Amp on %SHL @ M70, D3

Normal Probability Plot

**One-Way Analysis of Variance**

Analysis of Variance for %SHL 3

Source	DF	SS	MS	F	P
Amp	3	5.360	1.787	7.60	0.000
Error	36	8.467	0.235		
Total	39	13.828			

Individual 95% CIs For Mean
Based on Pooled StDev

Level	N	Mean	StDev	CI
70	10	1.9390	0.5058	(-----*-----)
80	10	1.7410	0.2893	(-----*-----)
90	10	2.3491	0.4224	(-----*-----)
100	10	2.6866	0.6503	(-----*-----)

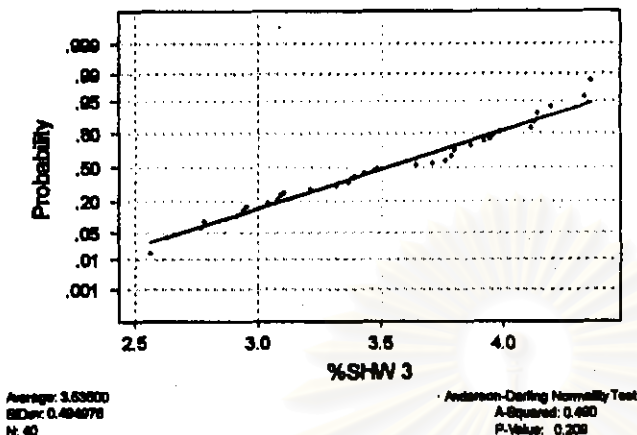
Pooled StDev = 0.4850

1.50 2.00 2.50 3.00

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Condition # 34 : Evaluate effect of Amp on %SHW @ M70, D3

Normal Probability Plot



One-Way Analysis of Variance

Analysis of Variance for %SHW 3

Source	DF	SS	MS	F	P
Amp	3	2.887	0.962	5.20	0.004
Error	36	6.668	0.185		
Total	39	9.555			

Individual 95% CIs For Mean
Based on Pooled StDev

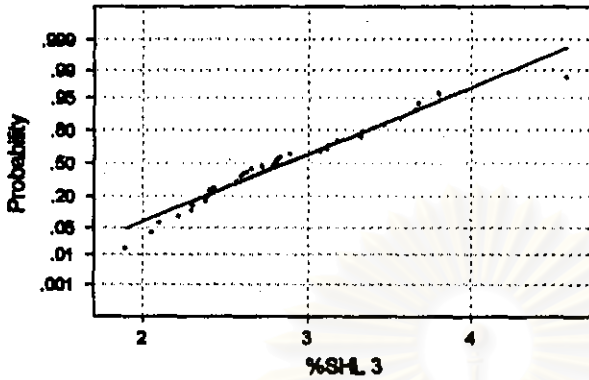
Level	N	Mean	StDev	CI Lower	CI Upper
70	10	3.3210	0.3924	2.9286	3.7134
80	10	3.2307	0.5206	2.6101	3.8513
90	10	3.7047	0.5072	3.1975	4.2119
100	10	3.8836	0.2423	3.6413	4.1259

Pooled StDev = 0.4304

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Condition # 35 : Evaluate effect of Amp on %SHL @ M100, D3

Normal Probability Plot



Average: 2.87668
 StDev: 0.567603
 N: 40

Anderson-Darling Normality Test
 A-Squared: 0.447
 P-Value: 0.287

One-Way Analysis of Variance

Analysis of Variance for %SHL 3

Source	DF	SS	MS	F	P
Amp	3	0.884	0.295	0.91	0.447
Error	36	11.681	0.324		
Total	39	12.565			

Individual 95% CIs For Mean
 Based on Pooled StDev

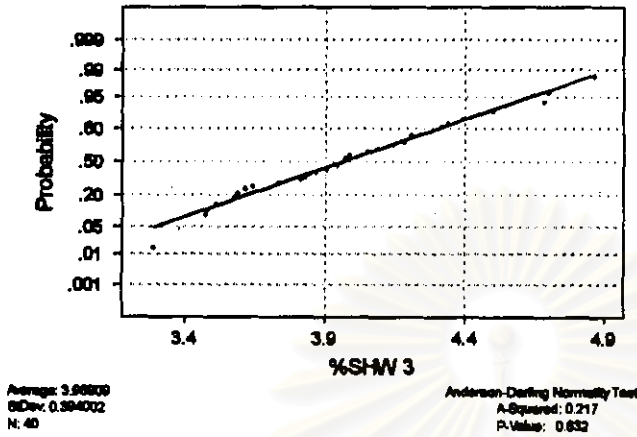
Level	N	Mean	StDev
70	10	2.8969	0.7371
80	10	2.6687	0.5420
90	10	3.0880	0.5514
100	10	2.8663	0.3959

Pooled StDev = 0.5696

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Condition # 36 : Evaluate effect of Amp on %SHW @ M100, D3

Normal Probability Plot



One-Way Analysis of Variance

Analysis of Variance for %SHW 3

Source	DF	SS	MS	F	P
Amp	3	0.112	0.037	0.23	0.877
Error	36	5.942	0.165		
Total	39	6.054			

Individual 95% CIs For Mean
Based on Pooled StDev

Level	N	Mean	StDev	CI Lower	CI Upper
70	10	3.9645	0.5017	3.4628	4.4662
80	10	3.8858	0.3984	3.4874	4.2842
90	10	4.0267	0.3189	3.7078	4.3456
100	10	3.9993	0.3848	3.6145	4.3841

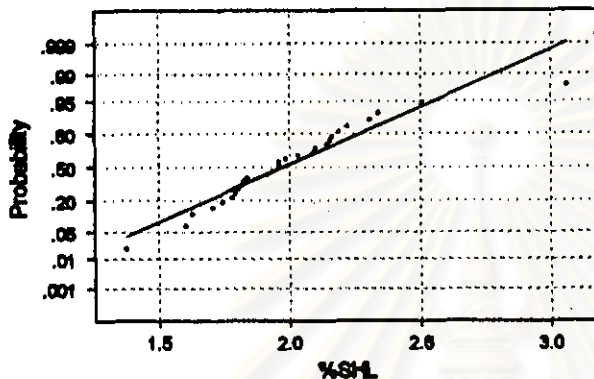
Pooled StDev = 0.4063

Appendix D : Result of ANOVA Test (Cont.)

• **Result ANOVA on Die's size Effect**

Condition # 37 : Effect of die's size @ M70, A70

Normal Probability Plot



Average: 1.93342
StDev: 0.321624
N: 30

Anderson-Darling Normality Test
A-Square: 0.911
P-Value: 0.181

One-Way Analysis of Variance

Analysis of Variance for %SHL

Source	DF	SS	MS	F	P
Die	2	0.231	0.115	1.13	0.339
Error	27	2.769	0.103		
Total	29	3.000			

Individual 95% CIs For Mean
Based on Pooled StDev

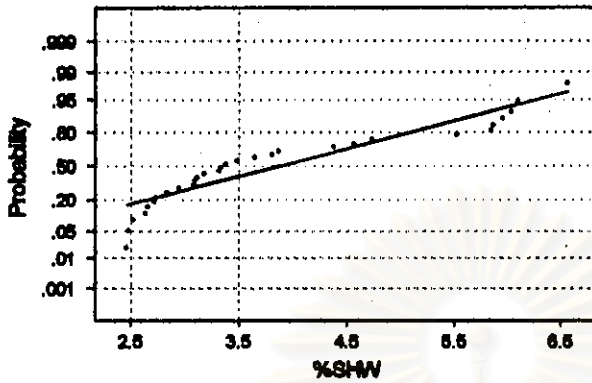
Level	N	Mean	StDev	CI Lower	CI Upper
1	10	1.9053	0.1446	1.616	2.194
2	10	2.1060	0.1757	1.755	2.457
3	10	1.9390	0.5058	0.927	2.951

Pooled StDev = 0.3202

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Condition #38 : Effect of die's size on %SHW @ M70, A70

Normal Probability Plot



Average: 3.69332
 StDev: 1.31801
 N: 30

Anderson-Darling Normality Test
 A-Squared: 1.088
 P-Value: 0.000

One-Way Analysis of Variance

Analysis of Variance for %SHW

Source	DF	SS	MS	F	P
Die	2	43.085	21.542	81.46	0.000
Error	27	7.140	0.264		
Total	29	50.225			

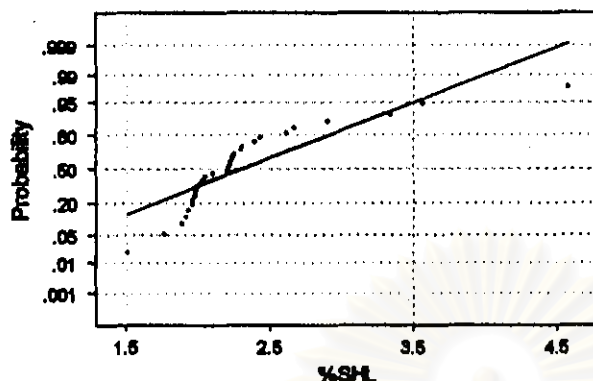
Individual 95% CIs For Mean
 Based on Pooled StDev

Level	N	Mean	StDev	CI	
1	10	5.5571	0.7402	(---*---)	
2	10	2.7920	0.3025	(---*---)	
3	10	3.3210	0.3924	(---*---)	

Pooled StDev = 0.5142

Condition #39 : Effect of die's size on %SHL @ M100, A70

Normal Probability Plot



Average: 2.31250
 StDev: 0.607276
 N: 30

Anderson-Darling Normality Test
 A-Statistic: 2.939
 P-Value: 0.000

One-Way Analysis of Variance

Analysis of Variance for %SHL

Source	DF	SS	MS	F	P
Die	2	5.298	2.649	13.25	0.000
Error	27	5.397	0.200		
Total	29	10.695			

Individual 95% CIs For Mean
 Based on Pooled StDev

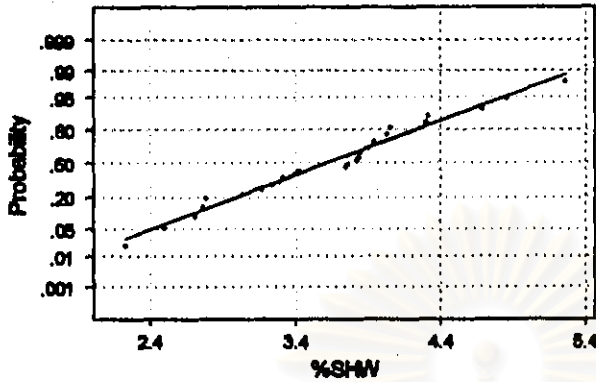
Level	N	Mean	StDev	CI Lower	CI Upper
1	10	2.1144	0.1341	1.846	2.383
2	10	1.9264	0.1959	1.534	2.318
3	10	2.8969	0.7371	1.423	4.371

Pooled StDev = 0.4471

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Condition #40 : Effect of die's size on %SHW @ M100, A70

Normal Probability Plot



Average: 3.42589
StDev: 0.707677
n: 30

Anderson-Darling Normality Test
A-Statistic: 0.265
P-Value: 0.415

One-Way Analysis of Variance

Analysis of Variance for %SHW

Source	DF	SS	MS	F	P
Die	2	8.438	4.219	18.73	0.000
Error	27	6.082	0.225		
Total	29	14.519			

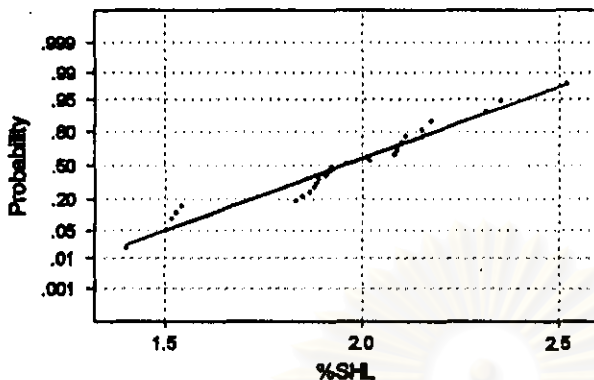
Individual 95% CIs For Mean
Based on Pooled StDev

Level	N	Mean	StDev	CI Lower	CI Upper
1	10	4.0361	0.5279	3.4082	4.6640
2	10	2.8770	0.3812	2.4958	3.2582
3	10	3.9645	0.5017	3.4628	4.4662

Pooled StDev = 0.4746

Condition #41 : Effect of die's size on %SHL @ M70, A80

Normal Probability Plot



Average: 1.8523
 StDev: 0.262764
 N: 30

Anderson-Darling Normality Test
 A-Statistic: 0.754
 P-Value: 0.044

One-Way Analysis of Variance

Analysis of Variance for %SHL

Source	DF	SS	MS	F	P
Die	2	0.7161	0.3581	7.52	0.003
Error	27	1.2860	0.0476		
Total	29	2.0022			

Individual 95% CIs For Mean
 Based on Pooled StDev

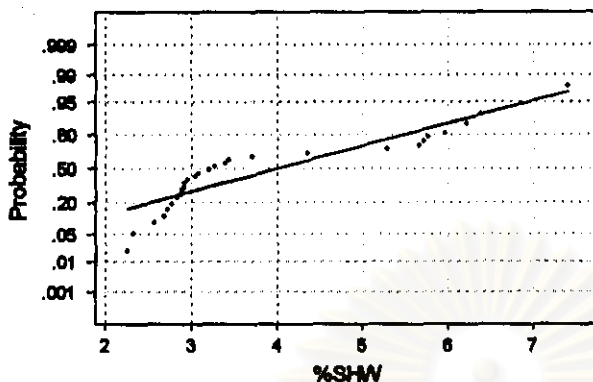
Level	N	Mean	StDev	CI Lower	CI Upper
1	10	2.0252	0.1130	1.8000	2.2504
2	10	2.0995	0.2155	1.6684	2.5306
3	10	1.7410	0.2693	1.2023	2.2797

Pooled StDev = 0.2182

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Condition #42 : Effect of die's size on %SHW @ M70, A80

Normal Probability Plot



Average: 4.04842
 StDev: 1.88412
 N: 30

Anderson-Darling Normality Test
 A-Statistic: 2.183
 P-Value: 0.000

One-Way Analysis of Variance

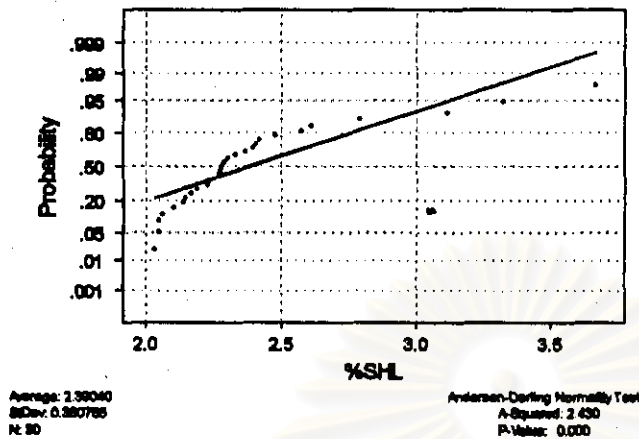
Analysis of Variance for %SHW

Source	DF	SS	MS	F	P
Die	2	66.906	33.453	133.05	0.000
Error	27	6.789	0.251		
Total	29	73.695			

Individual 95% CIs For Mean
 Based on Pooled StDev

Level	N	Mean	StDev	-----+-----+-----+-----		
1	10	6.1448	0.6226		(--*--)	
2	10	2.7728	0.3093	(--*--)		
3	10	3.2307	0.5206	(--*--)		
Pooled StDev =		0.5014		3.6	4.8	6.0

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Condition #43 : Effect of die's size on %SHL @ M100, A80**Normal Probability Plot****One-Way Analysis of Variance**

Analysis of Variance for %SHL

Source	DF	SS	MS	F	P
Die	2	1.182	0.591	5.28	0.012
Error	27	3.023	0.112		
Total	29	4.204			

Individual 95% CIs For Mean
Based on Pooled StDev

Level	N	Mean	StDev
1	10	2.2196	0.1159
2	10	2.2830	0.1692
3	10	2.6687	0.5420

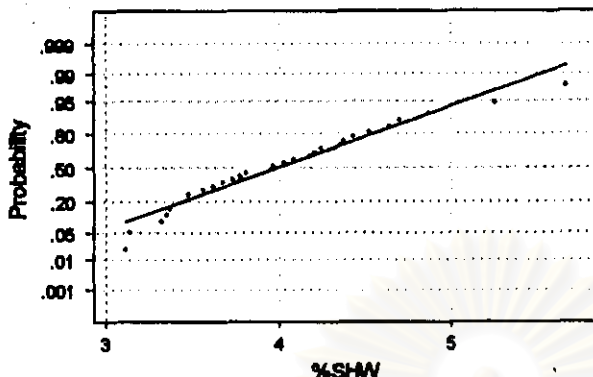
Pooled StDev = 0.3346

2.25 2.50 2.75

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Condition #44 : Effect of die's size on %SHW @ M100, A80

Normal Probability Plot



Average: 4.00889
StDev: 0.822211
N: 30

Anderson-Darling Normality Test
A-Squared: 0.390
P-Value: 0.429

One-Way Analysis of Variance

Analysis of Variance for %SHW

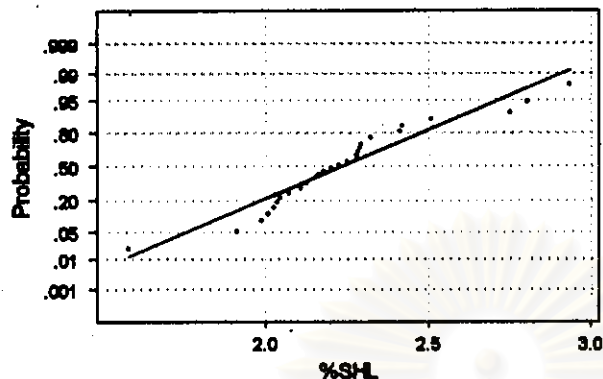
Source	DF	SS	MS	F	P
Die	2	7.007	3.504	22.42	0.000
Error	27	4.220	0.156		
Total	29	11.227			

Individual 95% CIs For Mean
Based on Pooled StDev

Level	N	Mean	StDev	CI Lower	CI Upper
1	10	4.6540	0.4798	3.70	5.61
2	10	3.4898	0.2827	2.92	4.06
3	10	3.8858	0.3984	3.09	4.68

Pooled StDev = 0.3953

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Condition #45 : Effect of die's size on %SHL @ M70, A90**Normal Probability Plot**

Average: 2.23291
 StDev: 0.269776
 N: 30

Anderson-Darling Normality Test
 A-Squared: 0.670
 P-Value: 0.022

One-Way Analysis of Variance

Analysis of Variance for %SHL

Source	DF	SS	MS	F	P
Die	2	0.2622	0.1311	1.92	0.167
Error	27	1.8483	0.0685		
Total	29	2.1106			

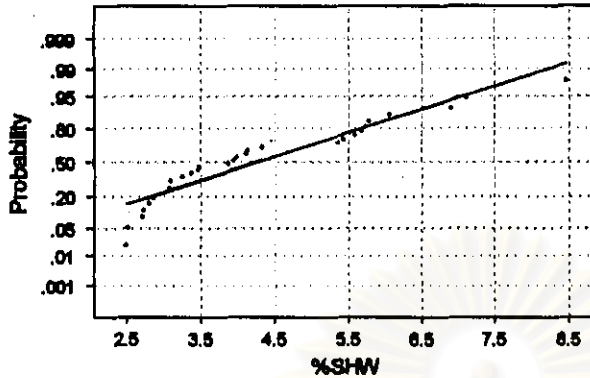
Individual 95% CIs For Mean
 Based on Pooled StDev

Level	N	Mean	StDev	-----+-----+-----+-----		
1	10	2.1202	0.1159	(------*-----)		
2	10	2.2285	0.1164	(------*-----)		
3	10	2.3491	0.4224	(------*-----)		
Pooled StDev = 0.2616				2.08	2.24	2.40

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Condition #46 : Effect of die's size on %SHW @ M70, A90

Normal Probability Plot



Average: 4.27370
StDev: 1.26656
N: 30

Anderson-Darling Normality Test
A-Squared: 1.138
P-Value: 0.006

One-Way Analysis of Variance

Analysis of Variance for %SHW

Source	DF	SS	MS	F	P
Die	2	59.484	29.742	67.14	0.000
Error	27	11.960	0.443		
Total	29	71.445			

Individual 95% CIs For Mean
Based on Pooled StDev

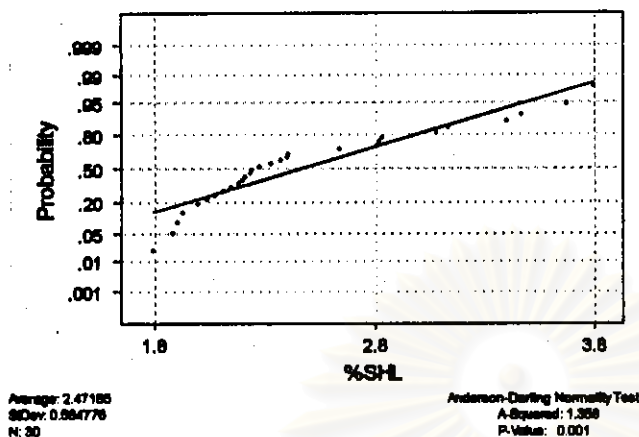
Level	N	Mean	StDev	CI Lower	CI Upper
1	10	6.2109	0.9847	4.21	8.21
2	10	2.9055	0.3194	2.26	3.55
3	10	3.7047	0.5072	2.68	4.73

Pooled StDev = 0.6656

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Condition #47 : Effect of die's size on %SHL @ M100, A90

Normal Probability Plot



One-Way Analysis of Variance

Analysis of Variance for %SHL

Source	DF	SS	MS	F	P
Die	2	5.916	2.958	23.95	0.000
Error	27	3.334	0.123		
Total	29	9.250			

Individual 95% CIs For Mean
Based on Pooled StDev

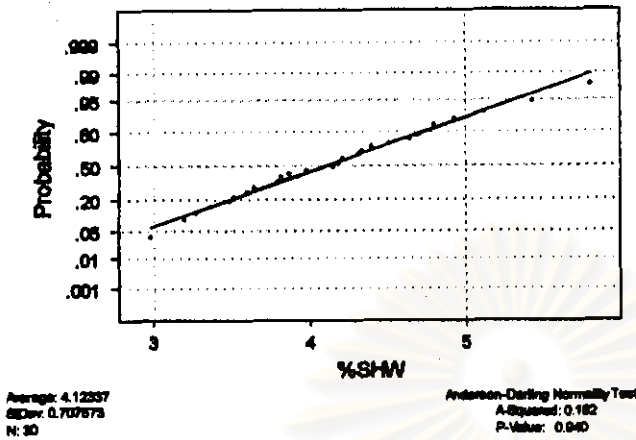
Level	N	Mean	StDev	CI Lower	CI Upper
1	10	2.2688	0.1049	2.0587	2.4789
2	10	2.0587	0.2354	1.5879	2.5295
3	10	3.0880	0.5514	2.3852	3.7908

Pooled StDev = 0.3514

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Condition #48 : Effect of die's size on %SHW @ M100, A90

Normal Probability Plot



One-Way Analysis of Variance

Analysis of Variance for %SHW

Source	DF	SS	MS	F	P
Die	2	10.862	5.431	40.09	0.000
Error	27	3.657	0.135		
Total	29	14.519			

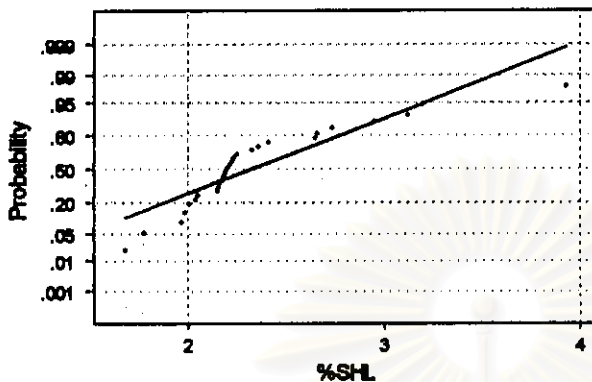
Individual 95% CIs For Mean
Based on Pooled StDev

Level	N	Mean	StDev	-----+-----+-----+-----		
1	10	4.9039	0.4426			(---*---)
2	10	3.4395	0.3297	(---*---)		
3	10	4.0267	0.3189		(---*---)	
Pooled StDev = 0.3680				3.60	4.20	4.80

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Condition #49 : Effect of die's size on %SHL @ M70, A100

Normal Probability Plot



Average: 2.33245
 StDev: 0.40070
 N: 30

Anderson-Darling Normality Test
 A-Statistic: 1.881
 P-Value: 0.000

One-Way Analysis of Variance

Analysis of Variance for %SHL

Source	DF	SS	MS	F	P
Die	2	1.890	0.945	5.78	0.008
Error	27	4.410	0.163		
Total	29	6.299			

Individual 95% CIs For Mean
 Based on Pooled StDev

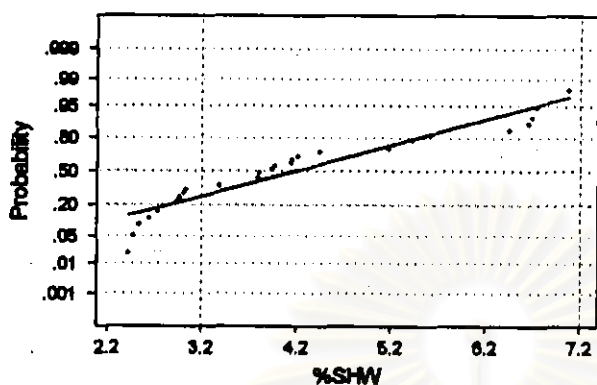
Level	N	Mean	StDev	CI Lower	CI Upper
1	10	2.1349	0.0979	2.0370	2.2328
2	10	2.1758	0.2399	1.9359	2.4157
3	10	2.6866	0.6503	2.0363	3.3369

Pooled StDev = 0.4041

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Condition #50 : Effect of die's size on %SHW @ M70, A100

Normal Probability Plot



Average: 4.19143
 StDev: 1.44616
 N: 30

Anderson-Darling Normality Test
 A-Squared: 1.030
 P-Value: 0.008

One-Way Analysis of Variance

Analysis of Variance for %SHW

Source	DF	SS	MS	F	P
Die	2	52.610	26.305	88.35	0.000
Error	27	8.039	0.298		
Total	29	60.649			

Individual 95% CIs For Mean
Based on Pooled StDev

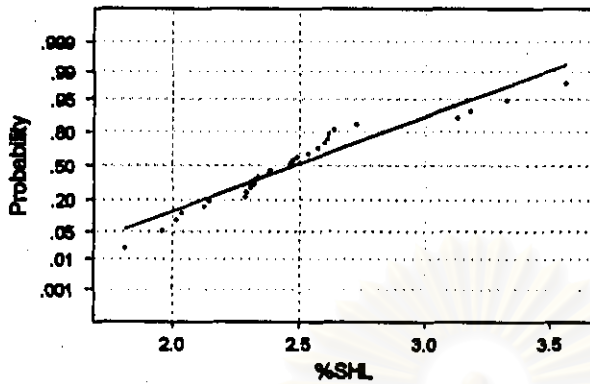
Level	N	Mean	StDev	95% CI	
1	10	5.9452	0.8859	(---*)	
2	10	2.7455	0.2228	(--*--)	
3	10	3.8836	0.2423	(--*--)	

Pooled StDev = 0.5457

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Condition #51 : Effect of die's size on %SHL @ M100, A100

Normal Probability Plot



Average: 2.45746
StDev: 0.28173
N: 30

Anderson-Darling Normality Test
A-Squared: 0.041
P-Value: 0.016

One-Way Analysis of Variance

Analysis of Variance for %SHL

Source	DF	SS	MS	F	P
Die	2	2.3713	1.1856	14.94	0.000
Error	27	2.1425	0.0794		
Total	29	4.5138			

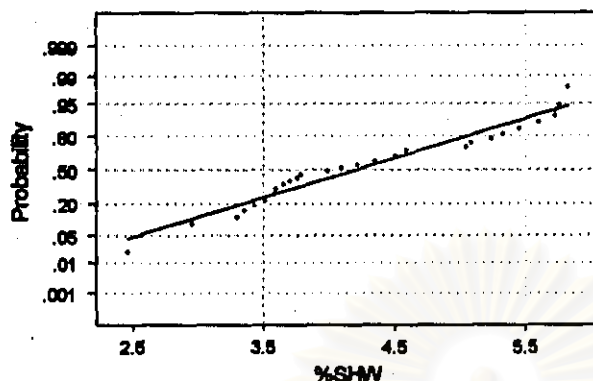
Individual 95% CIs For Mean
Based on Pooled StDev

Level	N	Mean	StDev
1	10	2.4024	0.1159
2	10	2.1936	0.2605
3	10	2.8663	0.3959

Pooled StDev = 0.2817

Condition #52 : Effect of die's size on %SHW @ M100, A100

Normal Probability Plot



Average: 4.21200
StDev: 0.871416
N: 30

Anderson-Darling Normality Test
A-Squared: 0.699
P-Value: 0.158

One-Way Analysis of Variance

Analysis of Variance for %SHW

Source	DF	SS	MS	F	P
Die	2	22.625	11.313	64.43	0.000
Error	27	4.741	0.176		
Total	29	27.366			

Individual 95% CIs For Mean
Based on Pooled StDev

Level	N	Mean	StDev	95% CI	
1	10	5.3665	0.3915	(---*---)	
2	10	3.2716	0.4748	(---*---)	
3	10	3.9993	0.3848	(---*---)	
Pooled StDev =		0.4190		3.20	4.00 4.80 5.60

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Appendix E : Calculation for Confidence Interval and Prediction Interval

A. Confidence Interval and Prediction Interval for M70 % SHW

From the experimental data as shown in appendix C

$$X = \begin{bmatrix} 1 & 70 & 0.118 & 0.397 \\ 1 & 70 & 0.118 & 0.397 \\ \vdots & \vdots & \vdots & \vdots \\ 1 & 70 & 1.9812 & 1.2141 \\ 1 & 70 & 1.9812 & 1.2141 \\ \vdots & \vdots & \vdots & \vdots \\ 1 & 100 & 0.096 & 0.165 \end{bmatrix}, 120 \text{ rows}$$

$$X^T \cdot X = \begin{bmatrix} 120 & 1.02 \cdot 10^4 & 87.808 & 71.044 \\ 1.02 \cdot 10^4 & 8.82 \cdot 10^5 & 7.464 \cdot 10^3 & 6.039 \cdot 10^3 \\ 87.808 & 7.464 \cdot 10^3 & 157.932 & 98.722 \\ 71.044 & 6.039 \cdot 10^3 & 98.722 & 66.355 \end{bmatrix}$$

$$(X^T \cdot X)^{-1} = \begin{bmatrix} 0.548 & -5.667 \cdot 10^{-3} & 0.108 & -0.232 \\ -5.667 \cdot 10^{-3} & 6.667 \cdot 10^{-5} & 0 & 0 \\ 0.108 & 0 & 0.265 & -0.511 \\ -0.232 & 0 & -0.511 & 1.023 \end{bmatrix}$$

If

$$x_0 = \begin{bmatrix} 1 \\ 80 \\ 0.500 \\ 0.700 \end{bmatrix}$$

Thus, $x_0^T = [1 \ 80 \ 0.5 \ 0.7]$

$$x_0^T (X^T X)^{-1} x_0 = 0.0617$$

From

regression equation on page 64,

$$M70 \%SHW = 1.38 + 0.0113 \text{ Amp} - 6.56 \text{ Cutting Edge} + 11.1 \text{ Edge Seal}$$

and $\sigma = 0.5697$

Substitute with x_0 , Amp = 80, Cutting Edge = 0.50 and Edge seal = 0.70, then

$$y_0 = 1.38 + 0.0113 (80) - 6.56 (0.5) + 11.1(0.7) = 6.774$$

To find 95% confidence interval :-

$$\begin{aligned} \text{Because, } s.e.(\hat{y}|x_0) &= \hat{\sigma} \sqrt{x_0'(XX)^{-1}x_0} \\ &= 0.5697 \times \sqrt{0.0617} \\ &= 0.1415 \end{aligned}$$

as such, the 95 % confidence interval is :-

$$\begin{aligned} &6.774 \pm t_{0.05/2, 120-3-1} \cdot 0.1415 \\ &6.774 \pm t_{0.025, 116} \cdot 0.1415 \\ &6.774 \pm 1.980 \cdot 0.1415 \\ &6.774 \pm 0.2802 \\ &(6.4938, 7.0542) \end{aligned}$$

To find 95% prediction interval :-

$$\begin{aligned} \text{Because, } s.e.(\hat{y}|x_0) &= \hat{\sigma} \sqrt{1+x_0'(XX)^{-1}x_0} \\ &= 0.5697 \times \sqrt{1.0617} \\ &= 0.5870 \end{aligned}$$

as such, the 95 % prediction interval for new observation is :-

$$\begin{aligned} &6.774 \pm t_{0.05/2, 120-3-1} \cdot 0.5870 \\ &6.774 \pm t_{0.025, 116} \cdot 0.5870 \\ &6.774 \pm 1.980 \cdot 0.5870 \\ &6.774 \pm 1.1623 \\ &(5.6117, 7.9363) \end{aligned}$$

Analysis Result of 95% Confidence Interval and Prediction Interval by Minitab

Regression Analysis

The regression equation is

$$M70 \%SHW = 1.38 + 0.0113 \text{ Amp} - 6.56 \text{ Cutting Edge} + 11.1 \text{ Edge Seal}$$

Predictor	Coef	StDev	T	P
Constant	1.3751	0.4219	3.26	0.001
Amp	0.011285	0.004652	2.43	0.017
Cutting	-6.5616	0.2935	-22.36	0.000
Edge Sea	11.0941	0.5763	19.25	0.000

S = 0.5697 R-Sq = 85.4% R-Sq(adj) = 85.1%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	220.920	73.640	226.89	0.000
Error	116	37.649	0.325		
Total	119	258.569			

Source	DF	Seq SS
Amp	1	1.910
Cutting	1	98.745
Edge Sea	1	120.265

Unusual Observations

Obs	Amp	T%shw, 0	Fit	StDev Fit	Residual	St Resid
4	70	4.3725	5.7952	0.1139	-1.4227	-2.55R
7	70	4.5638	5.7952	0.1139	-1.2314	-2.21R
16	80	7.3983	5.9081	0.0930	1.4903	2.65R
21	90	8.4601	6.0209	0.0930	2.4392	4.34R
31	100	4.4298	6.1338	0.1139	-1.7040	-3.05R

R denotes an observation with a large standardized residual

Fit	StDev Fit	95.0% CI	95.0% PI
6.7630	0.1415	(6.4826, 7.0435)	(5.6001, 7.9260)

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B. Confidence Interval and Prediction Interval for M70 % SHL

There is no need to calculate the confidence and prediction interval, due to the multiple regression equation is not appropriate to use.

C. Confidence Interval for M100 % SHW

From the experimental data as shown in appendix C

$$X = \begin{bmatrix} 1 & 70 & 0.118 & 0.397 \\ 1 & 70 & 0.118 & 0.397 \\ \vdots & \vdots & \vdots & \vdots \\ 1 & 70 & 1.9812 & 1.2141 \\ 1 & 70 & 1.9812 & 1.2141 \\ \vdots & \vdots & \vdots & \vdots \\ 1 & 100 & 0.096 & 0.165 \end{bmatrix}, 120 \text{ rows}$$

$$X^T \cdot X = \begin{bmatrix} 120 & 1.02 \cdot 10^4 & 87.808 & 71.044 \\ 1.02 \cdot 10^4 & 8.82 \cdot 10^5 & 7.46 \cdot 10^3 & 6.039 \cdot 10^3 \\ 87.808 & 7.46 \cdot 10^3 & 157.932 & 98.722 \\ 71.044 & 6.039 \cdot 10^3 & 98.722 & 66.355 \end{bmatrix}$$

$$(X^T \cdot X)^{-1} = \begin{bmatrix} 0.548 & -5.667 \cdot 10^{-3} & 0.108 & -0.232 \\ -5.667 \cdot 10^{-3} & 6.667 \cdot 10^{-5} & 0 & 0 \\ 0.108 & 0 & 0.265 & -0.511 \\ -0.232 & 0 & -0.511 & 1.023 \end{bmatrix}$$

If

$$x_0 = \begin{bmatrix} 1 \\ 80 \\ 0.500 \\ 0.700 \end{bmatrix}$$

Thus, $x_0^T = [1 \ 80 \ 0.5 \ 0.7]$,

$$x_0^T (X^T X)^{-1} x_0 = 0.0617$$

From regression equation on page 62,

$$M100 \%SHW = 2.02 + 0.0187 \text{ Amp} - 2.34 \text{ Cutting Edge} + 3.55 \text{ Edge Seal}$$

and $\sigma = 0.4650$

Substitute with x_0 , Amp = 80, Cutting Edge = 0.50 and Edge seal = 0.70, then

$$y_0 = 2.02 + 0.0187(80) - 2.34(0.5) + 3.55(0.7) = 4.8310$$

To find 95% confidence interval :-

$$\begin{aligned} \text{Because, } s.e.(\hat{y}|x_0) &= \hat{\sigma} \sqrt{x_0' (X'X)^{-1} x_0} \\ &= 0.4650 \times \sqrt{0.0617} \\ &= 0.1155 \end{aligned}$$

as such, the 95 % confidence interval is :-

$$\begin{aligned} &4.8310 \pm t_{0.05/2, 120-3-1} \cdot 0.1155 \\ &4.8310 \pm t_{0.025, 116} \cdot 0.1155 \\ &4.8310 \pm 1.980 \cdot 0.1155 \\ &4.8310 \pm 0.2287 \\ &(4.6023, 5.0597) \end{aligned}$$

To find 95% prediction interval :-

$$\begin{aligned} \text{Because, } s.e.(\hat{y}|x_0) &= \hat{\sigma} \sqrt{1 + x_0' (X'X)^{-1} x_0} \\ &= 0.4650 \times \sqrt{1.0617} \\ &= 0.4791 \end{aligned}$$

as such, the 95 % prediction interval for new observation is :-

$$\begin{aligned} &4.8310 \pm t_{0.05/2, 120-3-1} \cdot 0.4791 \\ &4.8310 \pm t_{0.025, 116} \cdot 0.4791 \\ &4.8310 \pm 1.980 \cdot 0.4791 \\ &4.8310 \pm 0.9487 \\ &(3.8823, 5.7797) \end{aligned}$$

Analysis Result of 95% Confidence Interval and Prediction Interval by Minitab

Regression Analysis

The regression equation is
 $M100 \%SHW = 2.02 + 0.0187 \text{ Amp} - 2.34 \text{ Cutting Edge} + 3.55 \text{ Edge Seal}$

Predictor	Coef	StDev	T	P
Constant	2.0167	0.3444	5.86	0.000
Amp	0.018734	0.003797	4.93	0.000
Cutting	-2.3443	0.2396	-9.79	0.000
Edge Sea	3.5457	0.4704	7.54	0.000

S = 0.4650 R-Sq = 65.9% R-Sq(adj) = 65.1%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	48.553	16.184	74.84	0.000
Error	116	25.085	0.216		
Total	119	73.639			

Source	DF	Seq SS
Amp	1	5.264
Cutting	1	31.005
Edge Sea	1	12.284

Unusual Observations

Obs	Amp	T%shW, 0	Fit	StDev Fit	Residual	St Resid
4	70	3.2392	4.4591	0.0930	-1.2199	-2.68R
13	80	5.6677	4.6464	0.0759	1.0213	2.23R
29	90	5.8049	4.8338	0.0759	0.9711	2.12R
71	100	2.5536	3.5505	0.0930	-0.9969	-2.19R
78	100	2.4581	3.5505	0.0930	-1.0924	-2.40R
87	70	4.8627	3.6881	0.0930	1.1746	2.58R
90	70	4.6881	3.6881	0.0930	1.0000	2.19R

R denotes an observation with a large standardized residual

Fit	StDev	Fit	95.0% CI	95.0% PI
4.8253	0.1155	(4.5964, 5.0542)	(3.8760, 5.7746)	

D. Confidence Interval and Prediction Interval for M100 % SHL

From the experimental data as shown in appendix C

$$X = \begin{pmatrix} 1 & 70 & 0.118 & 0.397 \\ 1 & 70 & 0.118 & 0.397 \\ \vdots & \vdots & \vdots & \vdots \\ 1 & 70 & 1.9812 & 1.2141 \\ 1 & 70 & 1.9812 & 1.2141 \\ \vdots & \vdots & \vdots & \vdots \\ 1 & 100 & 0.096 & 0.165 \end{pmatrix}, 120 \text{ rows}$$

$$X^T \cdot X = \begin{pmatrix} 120 & 1.02 \cdot 10^4 & 87.808 & 71.044 \\ 1.02 \cdot 10^4 & 8.82 \cdot 10^5 & 7.464 \cdot 10^3 & 6.039 \cdot 10^3 \\ 87.808 & 7.464 \cdot 10^3 & 157.932 & 98.722 \\ 71.044 & 6.039 \cdot 10^3 & 98.722 & 66.355 \end{pmatrix}$$

$$(X^T \cdot X)^{-1} = \begin{pmatrix} 0.548 & -5.667 \cdot 10^{-3} & 0.108 & -0.232 \\ -5.667 \cdot 10^{-3} & 6.667 \cdot 10^{-5} & 0 & 0 \\ 0.108 & 0 & 0.265 & -0.511 \\ -0.232 & 0 & -0.511 & 1.023 \end{pmatrix}$$

If

$$x_0 = \begin{pmatrix} 1 \\ 80 \\ 0.500 \\ 0.700 \end{pmatrix}$$

Thus,

$$x_0^T = [1 \ 80 \ 0.5 \ 0.7]$$

$$x_0^T (X^T X)^{-1} x_0 = 0.062$$

From regression equation on page 61,

$$M100 \%SHL = 2.72 + 0.00606 \text{ Amp} + 1.16 \text{ Cutting Edge} - 2.82 \text{ Edge Seal}$$

and $\sigma = 0.3642$

Substitute with x_0 , Amp = 80, Cutting Edge = 0.50 and Edge seal = 0.70, then

$$y_0 = 2.72 + 0.00606 (80) + 1.16 (0.5) - 2.82 (0.7) = 1.8108$$

To find 95% confidence interval :-

$$\begin{aligned} \text{Because, } s.e.(\hat{y}|x_0) &= \hat{\sigma} \sqrt{x_0' (XX)^{-1} x_0} \\ &= 0.3642 \times \sqrt{0.0617} \\ &= 0.0905 \end{aligned}$$

as such, the 95 % confidence interval is :-

$$\begin{aligned} &1.8108 \pm t_{0.05/2, 120-3-1} \cdot 0.0905 \\ &1.8108 \pm t_{0.025, 116} \cdot 0.0905 \\ &1.8108 \pm 1.980 \cdot 0.0905 \\ &1.8108 \pm 0.1791 \\ &(1.6317, 1.9899) \end{aligned}$$

To find 95% prediction interval :-

$$\begin{aligned} \text{Because, } s.e.(\hat{y}|x_0) &= \hat{\sigma} \sqrt{1 + x_0' (XX)^{-1} x_0} \\ &= 0.3642 \times \sqrt{1.0617} \\ &= 0.3753 \end{aligned}$$

as such, the 95 % prediction interval for new observation is :-

$$\begin{aligned} &1.8108 \pm t_{0.05/2, 120-3-1} \cdot 0.3753 \\ &1.8108 \pm t_{0.025, 116} \cdot 0.3753 \\ &1.8108 \pm 1.980 \cdot 0.3753 \\ &1.8108 \pm 0.7430 \\ &(1.0678, 2.5538) \end{aligned}$$

Analysis Result of 95% Confidence Interval and Prediction Interval by Minitab

Regression Analysis

The regression equation is

$$M100 \%SHL = 2.72 + 0.00606 \text{ Amp} + 1.16 \text{ Cutting Edge} - 2.82 \text{ Edge Seal}$$

Predictor	Coef	StDev	T	P
Constant	2.7183	0.2697	10.08	0.000
Amp	0.006062	0.002974	2.04	0.044
Cutting	1.1639	0.1876	6.20	0.000
Edge Sea	-2.8203	0.3685	-7.65	0.000

S = 0.3642 R-Sq = 47.4% R-Sq(adj) = 46.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	13.8617	4.6206	34.83	0.000
Error	116	15.3890	0.1327		
Total	119	29.2508			

Source	DF	Seq SS
Amp	1	0.5512
Cutting	1	5.5385
Edge Sea	1	7.7721

Unusual Observations

Obs	Amp	T, %sh L	Fit	StDev Fit	Residual	St Resid
84	70	3.5579	2.7891	0.0728	0.7688	2.15R
87	70	4.5774	2.7891	0.0728	1.7884	5.01R
91	80	2.0971	2.8497	0.0595	-0.7526	-2.09R
96	80	2.0462	2.8497	0.0595	-0.8035	-2.24R
99	80	3.6629	2.8497	0.0595	0.8132	2.26R
101	90	3.7944	2.9103	0.0595	0.8841	2.46R
107	90	1.8936	2.9103	0.0595	-1.0167	-2.83R
109	90	3.6760	2.9103	0.0595	0.7657	2.13R

R denotes an observation with a large standardized residual

Fit	StDev Fit	95.0% CI	95.0% PI
1.8110	0.0905	(1.6318, 1.9903)	(1.0675, 2.5545)

VITA



Rapeeporn Mahasaen was born on June 8th, 1973 at Uttaradit province of Thailand. In academic year 1994, She obtains her Bachelor's Degree in Industrial Engineering from Chulalongkorn University. After graduated, she started her career with 3M (Minnesota Mining and Manufacturing) Thailand Co., Ltd. as a quality engineer.

While working for 3M, she continued her studying and successfully graduate in a Master Degree of Engineering Management from the Regional Center for Manufacturing System Engineering in academic year 1998. The latest positions of Rapeeporn at 3M Thailand Co., Ltd. are Advance Quality Engineer and ISO Coordinator.

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