taguchi method

test case 2

Table 5.1. Process data

Data No.	"B" temp	"C" temp	P 1	P 2	Pre-ht time	Manuf time	Yield
1	575.0	274.0	205.5	210.5	5.0	180.0	81.55%
2	575.0	304.0	207.5	218.5	6.0	120.0	82.99%
3	570.0	279.0	199.5	207.5	7.0	120.0	83.03%
4	577.0	205.0	173.0	164.0	7.0	120.0	84.56%
5	573.0	254.0	160.0	164.0	7.0	120.0	84.60%
6	577.0	216.0	176.0	168.0	6.0	120.0	85.52%
7	582.0	222.5	171.0	167.0	5.0	180.0	89.47%

avg = 84.53

Table 5.2. Data in the unit space and the average values

Sample No.	"B" temp	"C" temp	P 1	P 2	Pre-ht time	Manuf time	Yield
4	577.0	205.0	173.0	164.0	7.0	120.0	84.56%
5	573.0	254.0	160.0	164.0	7.0	120.0	84.60%
Average	575.0	229.5	166.5	164.0	7.0	120.0	84.58%

Table 5.3. Signal data

Data No.	"B" temp	"C" temp	P 1	P 2	Pre-ht time	Manuf time	Yield
1	575.0	274.0	205.5	210.5	5.0	180.0	81.55%
2	575.0	304.0	207.5	218.5	6.0	120.0	82.99%
3	570.0	279.0	199.5	207.5	7.0	120.0	83.03%
6	577.0	216.0	176.0	168.0	6.0	120.0	85.52%
7	582.0	222.5	171.0	167.0	5.0	180.0	89.47%

Table 5.4. Normalized signal data

Data No.	"B" temp	"C" temp	P 1	P 2	Pre-ht time	Manuf time	Yield
1	0.0	44.5	39.0	46.5	−2.0	60.0	−3.03%
2	0.0	74.5	41.0	54.5	−1.0	0.0	−1.59%
3	−5.0	49.5	33.0	43.5	0.0	0.0	−1.55%
6	2.0	−13.5	9.5	4.0	−1.0	0.0	0.94%
7	7.0	−7.0	4.5	3.0	−2.0	60.0	4.89%

Effective divider

$$
\begin{aligned}
r &= M_1^2 + M_2^2 + \cdots + M_l^2 \\
&= (-0.0303)^2 + (-0.0159)^2 + \cdots + 0.0489^2 = 0.00389
\end{aligned}
\tag{5.3}
$$

Total variation

$$
\begin{aligned}
S_{T1} &= X_{11}^2 + X_{21}^2 + \cdots + X_{l1}^2 \\
&= 0.0^2 + 0.0^2 + \cdots + 7.0^2 = 78.0 \quad (\mathrm{f}=5)
\end{aligned}
\tag{5.4}
$$

Variation of proportional term

$$
\begin{aligned}
S_{\beta 1} &= \frac{(M_1 X_{11} + M_2 X_{21} + \cdots + M_l X_{l1})^2}{r} \\
&= \frac{\{(-0.0303) \times 0.0 + (-0.0159) \times 0.0 + \cdots + 0.0489 \times 7.0\}^2}{0.00389} \\
&= 49.4433 \qquad (\mathrm{f}=1)
\end{aligned}
\tag{5.5}
$$

Error variation

$$S_{e1} = S_{T1} - S_{\beta 1} = 78.0 - 49.4433 = 28.5567 \qquad (f=4) \tag{5.6}$$

Error variance

$$V_{e1} = \frac{S_{e1}}{l-1} = \frac{28.5567}{4} = 7.1392 \tag{5.7}$$

Therefore, the proportional coefficient β and the SN ratio η can be found as follows:
Proportional Coefficient:

$$\begin{aligned} \beta_1 &= \frac{M_1 X_{11} + M_2 X_{21} + \cdots + M_l X_{l1}}{r} \\ &= \frac{(-0.0303)\times 0.0 + (-0.0159)\times 0.0 + \cdots + 0.0489 \times 7.0}{0.00389} \\ &= 112.7296 = 112.73 \end{aligned} \tag{5.8}$$

Given the SN ratio η_1 $S_{\beta 1} > V_{e1}$, the equation works out as follows. The SN ratio in this case is a duplicate ratio.

$$\eta_1 = r \frac{\frac{1}{r}\left(S_{\beta 1} - V_{e1}\right)}{V_{e1}} = \frac{\frac{1}{0.00389}(49.4433 - 7.1392)}{7.1392} = 1523.01 \tag{5.9}$$

Table 5.5. The proportional coefficients β and the SN ratios η

β, η	"B" temp	"C" temp	P 1	P 2	Pre-ht time	Manuf time
β	112.73	−968.81	–523.23	–710.78	−7.89	286.84
η	1523.01	315.26	71.21	140.46	0.00	0.00

$$\hat{M}_i = \frac{\eta_1 \times \frac{X_{i1}}{\beta_1} + \eta_2 \times \frac{X_{i2}}{\beta_2} + \eta_3 \times \frac{X_{i3}}{\beta_3} + \eta_4 \times \frac{X_{i4}}{\beta_4} + \eta_5 \times \frac{X_{i5}}{\beta_5} + \eta_6 \times \frac{X_{i6}}{\beta_6}}{\eta_1 + \eta_2 + \eta_3 + \eta_4 + \eta_5 + \eta_6}$$

$$= \frac{1523.01 \times \frac{X_{i1}}{112.73} + 315.26 \times \frac{X_{i2}}{(-968.81)} + 71.21 \times \frac{X_{i3}}{(-523.23)} + 140.46 \times \frac{X_{i4}}{(-710.78)} + 0 + 0}{1523.01 + 315.26 + 71.21 + 140.46 + 0 + 0} \tag{5.10}$$

$$\hat{M}_1 = \frac{1523.01 \times \frac{0.0}{112.73} + 315.26 \times \frac{44.5}{(-968.81)} + 71.21 \times \frac{39.0}{(-523.23)} + 140.46 \times \frac{46.5}{(-710.78)} + 0 + 0}{1523.01 + 315.26 + 71.21 + 140.46 + 0 + 0}$$

$$= \frac{(-28.98)}{2049.95} = -0.0141 \tag{5.11}$$

Table 5.6. Actual and integrated estimate values of yields of signal data

Data No.	**Actual value M**	**Estimated value M**
1	−3.03%	−1.41%
2	−1.59%	−1.98%
3	−1.55%	−4.72%
6	0.94%	1.43%
7	4.89%	4.67%

Linear equation

$$\begin{aligned} L &= M_1\hat{M}_1 + M_2\hat{M}_2 + \cdots + M_l\hat{M}_l \\ &= (-0.0303)\times(-0.0141) + (-0.0159)\times(-0.0198) + \cdots + 0.0489\times 0.0467 \\ &= 0.00389 \end{aligned} \tag{5.12}$$

Effective divider

$$\begin{aligned} r &= M_1^2 + M_2^2 + \cdots + M_l^2 \\ &= (-0.0303)^2 + (-0.0159)^2 + \cdots + 0.0489^2 = 0.00389 \end{aligned} \tag{5.13}$$

Total variation

$$\begin{aligned} S_T &= \hat{M}_1^2 + \hat{M}_2^2 + \cdots + \hat{M}_l^2 \\ &= (-0.0141)^2 + (-0.0198)^2 + \cdots + 0.0467^2 = 0.00520 \quad (\mathrm{f}=5) \end{aligned} \tag{5.14}$$

Variation S_β of a proportional term

$$S_\beta = \frac{L^2}{r} = \frac{0.00389^2}{0.00389} = 0.00389 \quad (\mathrm{f}=1) \tag{5.15}$$

Error variation

$$S_e = S_T - S_\beta = 0.00520 - 0.00389 = 0.00131 \quad (\mathrm{f}=4) \tag{5.16}$$

Error variance

$$V_e = \frac{S_e}{l-1} = \frac{0.00131}{4} = 0.00033 \tag{5.17}$$

Using the above computation results, the SN ratio η for general estimation can be found as follows:

$$\eta = 10\log\left(\frac{\frac{1}{r}(S_\beta - V_e)}{V_e}\right) = 10\log\left(\frac{\frac{1}{0.00389}(0.00389 - 0.00033)}{0.00033}\right) \tag{5.18}$$
$$= 10\log(2795.97853) = 34.47\,(db)$$

Table 5.7. Orthogonal array L_{12} and the layout of items

No.	"B" temp	"C" temp	P 1	P 2	Pre-heat time	Manuf time	*e*	*e*	*e*	*e*	*e*	Integrated estimate SN ratio (db)
1	1	1	1	1	1	1	1	1	1	1	1	34.47
2	1	1	1	1	1	2	2	2	2	2	2	34.47
3	1	1	2	2	2	1	1	1	2	2	2	33.87
4	1	2	1	2	2	1	2	2	1	1	2	32.64
5	1	2	2	1	2	2	1	2	1	2	1	33.16
6	1	2	2	2	1	2	2	1	2	1	1	31.83
7	2	1	2	2	1	1	2	2	1	2	1	24.99
8	2	1	2	1	2	2	2	1	1	1	2	24.16
9	2	1	1	2	2	2	1	2	2	1	1	24.29
10	2	2	2	1	1	1	1	2	2	1	2	21.48
11	2	2	1	2	1	2	1	1	1	2	2	18.53
12	2	2	1	1	2	1	2	1	2	2	1	20.65

Table 5.8. Integrated estimate SN ratio (db) auxiliary table (averages by level)

Item	Level 1	Level 2
“B” temperature	33.41	22.35
“C” temperature	29.37	26.38
Pressure 1	27.51	28.25
Pressure 2	28.06	27.69
Preheating time	27.62	28.13
Manufacturing time	28.02	27.74

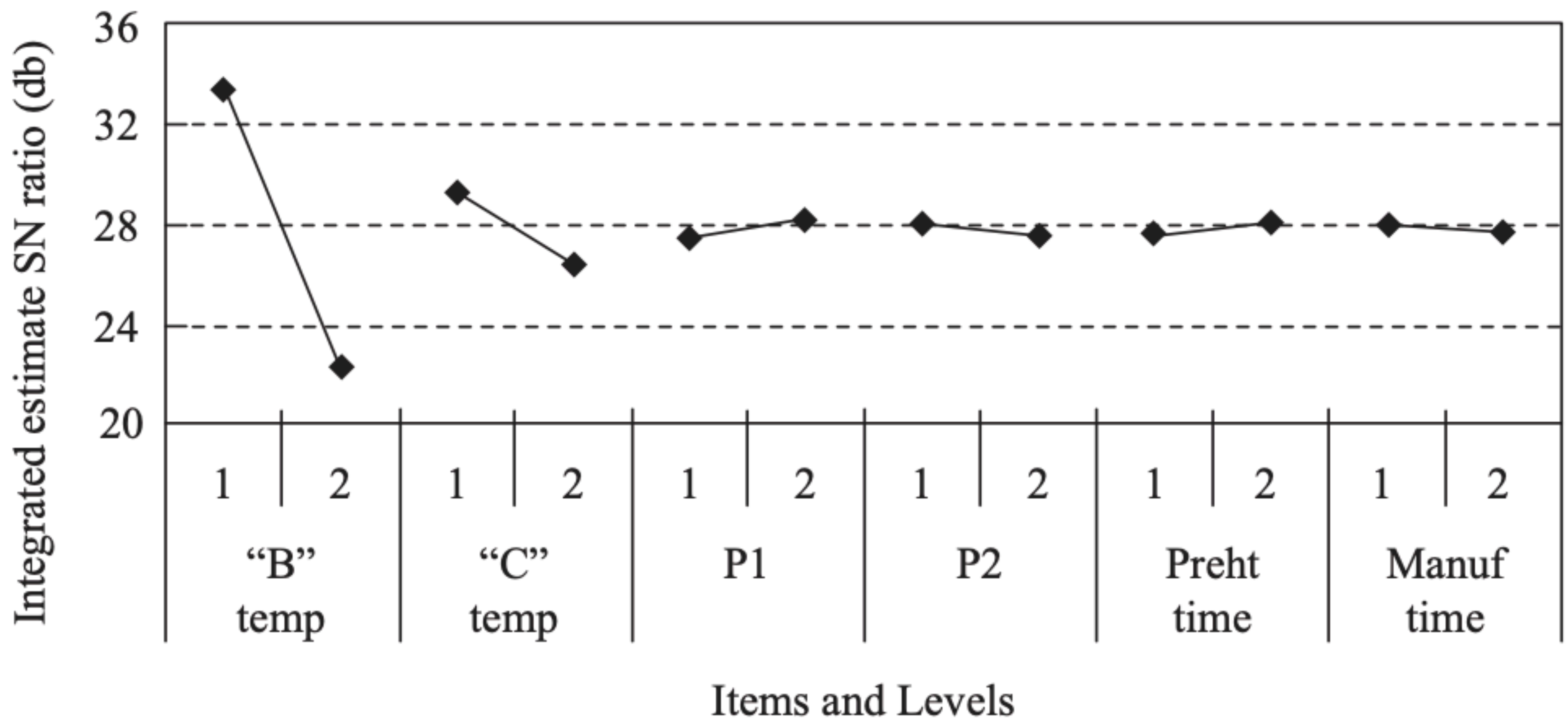

Figure 5.3. Factorial effects for the six items.

Table 5.9. Comparison of integrated estimate SN ratios (db)

Case	Items used	Integrated estimate SN ratio (db)
1	All items	34.47
2	"B" temperature, "C" temperature	33.87

Table 5.10. Unknown data

Data No.	"B" temp	"C" temp	P 1	P 2	Pre-ht time	Manuf time	Yield
<1>	563.0	306.5	185.5	183.5	2.8	60.0	unknown

Table 5.11. Normalized unknown data

Data No.	"B" temp	"C" temp	P 1	P 2	Pre-ht time	Manuf time	Yield
<1>	–12.0	77.0	19.0	19.5	–4.2	–60.0	unknown

integrated estimate yield value is computed using equation (5.10).

$$\hat{M}_{<1>} = \frac{1523.01 \times \dfrac{(-12.0)}{112.73} + 315.26 \times \dfrac{77.0}{(-968.81)} + 71.21 \times \dfrac{19.0}{(-523.23\ )} + 140.46 \times \dfrac{19.5}{(-710.78)} + 0 + 0}{1523.01 + 315.26 + 71.21 + 140.46 + 0 + 0}$$

$$= \frac{-193.62}{2049.95} = -0.0945 \tag{5.19}$$

the integrated estimate value $\hat{y}_1$ for the yield of Signal Data No. 1 is found as follows:

$$\hat{y}_1 = \hat{M}_1 + M_0 = -1.41 + 84.58 = 83.17\ (\%) \qquad (5.20)$$

For the unknown data as well, the integrated estimate value $\hat{y}$ of the yield is found by adding the yield average value M_0 (= 84.58) of the Unit Space to the likewise normalized value . Therefore, the yield's integrated estimate value $\hat{y}$<1> for unknown data <1> will be:

$$\hat{y}_{<1>} = \hat{M}_{<1>} + M_0 = -9.45 + 84.58 = 75.13\ (\%) \qquad (5.21)$$

Table 5.12. The Actual value y and the integrated estimate value $\hat{y}$ of the yields for signal data and unknown data

No.		Actual value y	Integrated estimate value $\hat{y}$
Signal Data	1	81.55%	83.17%
	2	82.99%	82.60%
	3	83.03%	79.86%
	6	85.52%	86.01%
	7	89.47%	89.25%
Unknown data	<1>	73.30%	75.13%

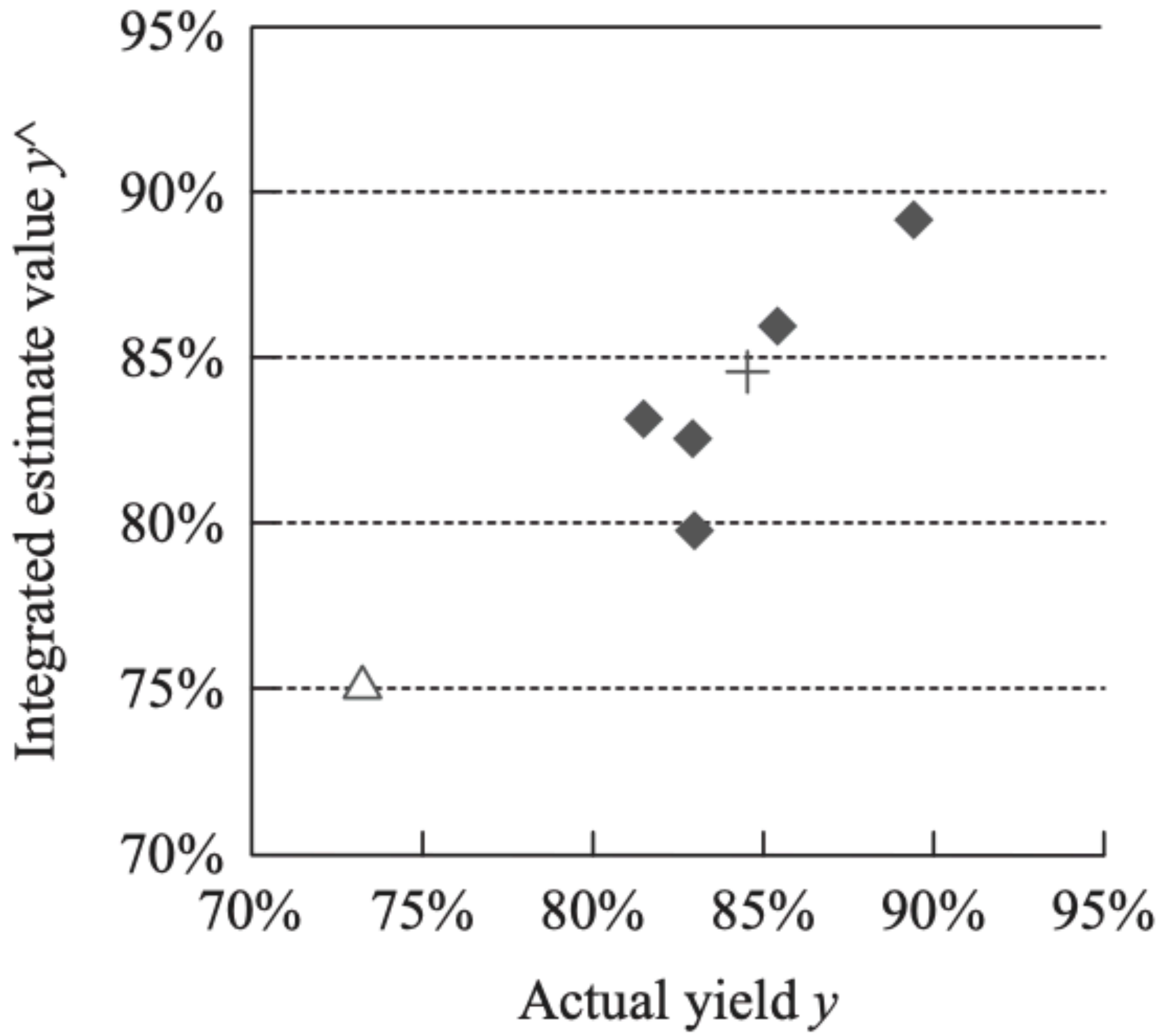

Figure 5.4. Actual yield value y and integrated estimate value $\hat{y}$.

We learn from the figure that the plotted dots overlap rather closely, almost a 45° straight line, indicating that the Signal Data as well as the unknown data are fairly good estimations.