CASE 29

Parameter Design for a Foundry Process Using Green Sand

Abstract: Because of its low cost and easy recycling, green sand casting (casting method using green sand) is used in many cast products. Since the caking strength of green sand tends to vary widely when mixed and it fluctuates over time after being mixed, it is considered difficult to control on actual production lines. Therefore, by applying parameter design we attempted to determine an optimal manufacturing condition such that we can improve its caking strength after kneading and make it more robust to time-lapsed change.

1. Introduction

The conventional evaluation method has used the compression strength that is measured by a cylindrical sample filled firmly with green sand. However, since some green sand is brittle even if it has a high compression strength, we considered not only the strength but also displacement up to a breaking point as important elements. Thus, after preparing a sample of green sand filled in an upper-and-lower-split cylinder (Figure 1), we measured the relationship between the displacement and load by pulling the sample vertically. As a generic function, we assumed that there exists a proportionality of $y = \beta M$ between the displacement, M, and the load, y, according to Hooke's law.

As a signal factor, we selected the displacement, M, when performing a tension experiment; and for the factor levels, we picked up the next five, M = 0.02, 0.04, 0.06, 0.08, and 0.10 mm. Considering the fact that a stoppage time at a production line strongly affects the caking strength, as a noise factor we chose a lapsed time after mixture of green sand with two levels, N_1 = 0 min and N_2 = 60 min.

2. SN Ratio and Sensitivity

Based on the result of the pull test, we calculated using the SN ratio and sensitivity zero-point proportional equations. Using the data of experiment 1, in Table 1 we show the calculation procedure of SN ratio and sensitivity.

Total variation:

$$S_T = 28.3^2 + 47.9^2 + \cdots + 2.4^2 + 1.5^2 = 6880.46 \qquad (f = 10) \tag{1}$$

Linear equations:

$$L_1 = (0.02)(28.3) + (0.04)(47.9) + \cdots + (0.10)(8.3) = 7.168$$

$$L_2 = (0.02)(34.2) + (0.04)(18.1) + \cdots + (0.10)(1.5) = 2.002 \tag{2}$$

Effective divider:

$$r = 0.02^2 + 0.04^2 + \cdots + 0.10^2 = 0.022 \tag{3}$$

Variation of proportional term:

$$S_\beta = \frac{(L_1 + L_2)^2}{2r} = 1911.111 \qquad (f = 1) \tag{4}$$

 Taguchi's Quality Engineering Handbook. Genichi Taguchi, Subir Chowdhury and Yuin Wu

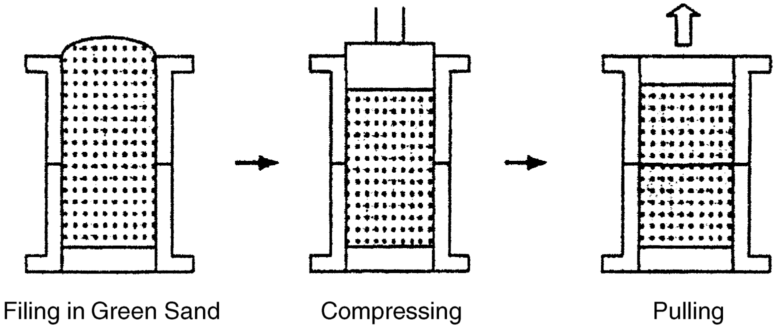

Figure 1
Method for measurement of caking strength

Variation of differences of proportional term:

$$S_{N\beta} = \frac{L_1^2 + L_2^2}{r} - S_\beta = 606.536 \qquad (f = 1) \qquad (5)$$

Error variation:

$$S_e = S_T - S_\beta - S_{N\beta} = 4362.819 \qquad (f = 8) \qquad (6)$$

Error variance:

$$V_e = \frac{S_e}{8} = 545.352 \qquad (7)$$

Total error variance:

$$V_N = \frac{S_{N\beta} + S_e}{9} = 552.151 \qquad (8)$$

SN ratio:

$$\eta = 10 \log \frac{(1/2r)(S_\beta - V_e)}{V_N} = 17.50 \text{ dB} \qquad (9)$$

Sensitivity:

$$S = 10 \log \frac{1}{2r}(S_\beta - V_e) = 44.92 \text{ dB} \qquad (10)$$

3. Optimal Configuration and Results of Confirmatory Experiment

As shown in Table 2, we selected as control factors, based on our technical knowledge, eight factors that significantly influence caking strength. Figure 2 illustrates the response graphs.

Considering the response graphs of the SN ratio and sensitivity, we determined that the optimal configuration is $A_1B_3C_3D_3E_1F_1G_1H_1$. To verify the estimation, we performed confirmatory experiments both at the optimal and at the initial configurations. Table 3 shows estimations of the SN ratio and sensitivity and results of the confirmatory experiments. The fact that with respect to both SN ratio and sensitivity, the gains obtained in the confirmatory

Table 1
Results of pull test (mm)

	Signal Factor (Displacement of Green Sand)				
Noise Factor	M_1 (0.02)	M_2 (0.04)	M_3 (0.06)	M_4 (0.08)	M_5 (0.10)
N_1 (0 min)	28.3	47.9	44.4	14.8	8.3
N_2 (60 min)	34.2	18.1	4.2	2.4	1.5

Table 2
Control factors and levels

	Control Factor	Level 1	Level 2	Level 3
A:	amount of water before kneading	Small	Large	—
B:	CB value after kneading	Low	Mid	High
C:	amount of bonding agent	No	Small	Large
D:	amount of surface stabilizing agent	No	Small	Large
E:	amount of micropowder sand	No	Small	Large
F:	amount of coal powder	No	Small	Large
G:	amount of new sand	Small	Mid	Large
H:	maturation time	Short	Mid	Long

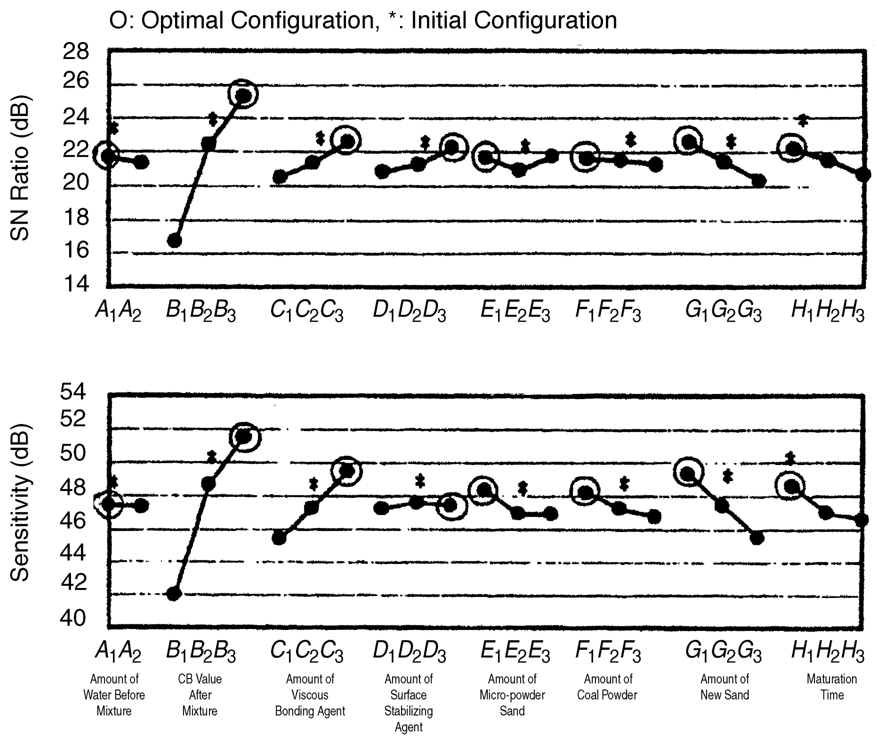

Figure 2
Response graphs

Table 3
SN ratios and sensitivity and results of experiments

	SN		Sensitivity	
	Prediction	**Confirmation**	**Prediction**	**Confirmation**
Optimum	27.61	33.89	55.55	55.96
Baseline	22.20	29.13	48.51	49.55
Gain	5.41	4.76	7.04	6.41

experiments were proven to be almost the same as the estimations reveals the validity of the experiments.

In addition, we confirmed the effects on quality characteristics. Currently, as a quality characteristic to evaluate the viscous bonding strength of green sand, we used the jolt toughness (JT) test, which can be implemented easily on production lines. As Figure 3 illustrates, this test measures how many impacts are needed to break a test sample, with repeated impacts on the sample, firmly filled with green sand.

Table 4 summarizes the JT values measured at both the optimal and initial configurations. For the JT value right after mixing, we obtained a result of 64 times at the optimal configuration rather than 33 at the initial configuration, thereby improving the viscous caking strength by 94%. On the other hand, for the decreased JT value 60 minutes after mixing, there was only a 25% drop, from 64 times to 48 times at the optimal configuration, whereas a 52% fall from 33 times to 16 times took place at the initial configuration. According to this result in the confirmatory experiments for the objective quality characteristic, we can see that it is possible to improve the caking strength of green sand by changing the configuration from initial to optimal.

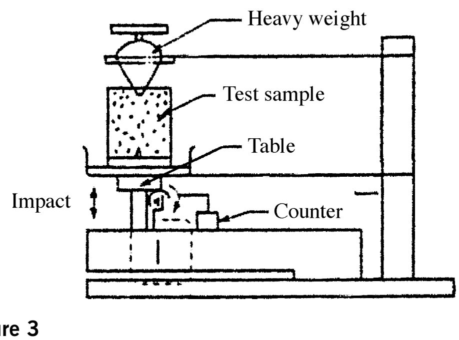

Figure 3
Jolt toughness test

Table 4
Jolt toughness values

Configuration	**Right after Kneading (N_1)**	**60 min after Kneading (N_2)**
Optimal	64	48
Initial	33	16

Reference

Yuji Hori and Satomi Shinoda, 1998. Parameter design on a foundry process using green sand. *Quality Engineering*, Vol. 6, No. 1, pp. 54–59.

This case study is contributed by Yuji Hori.