Optimization of vacuum casting process parameters using Taguchi method

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ABSTRACT – This paper investigates the optimization of vacuum casting process by using Taguchi method. In order to optimize these 3 parameters which are resin temperature, mould temperature and vacuum pressure time, the L'9 orthogonal array was used. From the results, it shows that the optimum parameters that can minimize the shrinkage are resin temperature (30 °C), mould temperature (60 °C) and vacuum pressure time (5 min.). The study demonstrates that better dimensional accuracy of vacuum casting process can be optimized using Taguchi method.

1. INTRODUCTION

According to Radu and Fratila [1], vacuum casting is a modern technique that allows the manufacturing of pieces in small batches and individual fabrication at minimum price and shorter time. This technique aids to build intricate prototype parts with similar form details and surface quality of the duplicate master model. Osman et al. [2] has carried out a research to determine the optimization parameter for holes diameter accuracy in dry drilling process of AISI D2 Tool Steel using Taguchi method. In recent years, the rapid growth of interest in the Taguchi method has led to numerous applications of the method in a world-wide range of industries and nations [3]. The aim of this study is optimizing vacuum casting parameter by Taguchi method.

2. METHODOLOGY

In this study, Taguchi method was used in optimizing vacuum casting parameter. Three factors with three levels for each were considered. By using orthogonal array, L-9 orthogonal array is selected. Table 1 shows L-9 orthogonal array with 3 parameters which are resin temperature (°C), mould temperature (°C) and vacuum pressure time (min).

Table 1 Factors and their levels.

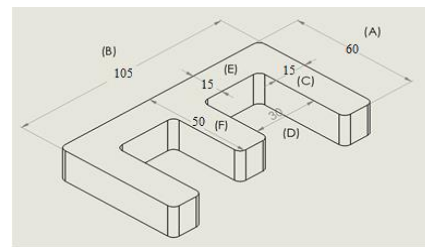| Serial	Factor	Levels		
		1	**2**	**3**
A	Resin temp. (°C)	20	25	30
B	Mould Temp. (°C)	60	70	80
C	Vacuum Time (min)	5	10	15

Figure 1 Vacuum casting specimens with six sections to be measured.

The experiment runs for 9 specimens and measure 6 section as shown in Figure 1. Computer Measuring Machine (CMM) was used to record the data. Dimension at Section B was assigned as major section. Each dimension was measured three times and the average is considered. The value of shrinkage is calculated by using the Equation (1)

$$\text{Shrinkage value} = Lc - Lm \tag{1}$$

Where, Lc is the original dimension of CAD model and Lm is the measured dimension.

Minitab software has been used in analysis the data. The values of Signal to Noise Ratio (S/N Ratio) and means were obtained throughout the analysis. Using 'smaller is better' equation in the signal to ratio, the graphs of main effects for signal to noise ratios and means are plotted. For smaller is better (S/N Ratio) was calculated based on Equation (2).

$$S/N = -10*log \left(\Sigma \left(Y^2 \right)/n \right) \tag{2}$$

Where, Y is responses for the given factor level combination and n is number of responses in the factor level combination.

3. RESULTS AND DISCUSSION
3.1 Signal to noise ratio and mean

Table 2 shows the values of design experiment L-9 and section B shrinkage value. Figure 2 and 3 show the main effect plot for SN ratios and Mean. In the SN ratio graph, the optimum parameter is observed by the highest level plotted. This is because the highest value of SN ratio means it has lower effect of noise factor. Based on the Section B main effect plot for S/N ratios, the highest

point plotted for resin temperature is at level 3 (30°C). For mould temperature, the highest point is at level 1 (60°C). Meanwhile for vacuum pressure time, the highest point is at level 1 (5 min).

Mitra et al. [4] reports the main effect is a value which shows the extent of influence of a factor on the response. Hence, the combination for optimum parameter condition is A3B1C1 (30°C, 60°C, 5 min) that will give the optimum shrinkage value for section B dimension.

Table 2 Experiment L-9 and section B shrinkage results.

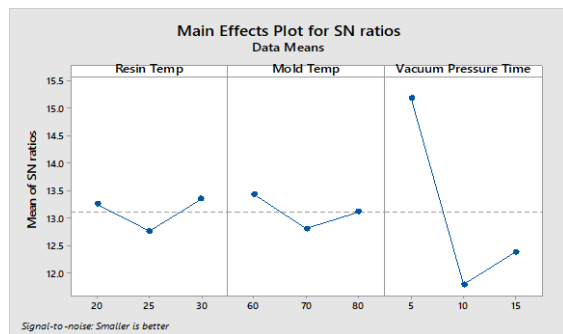| Run	Resin temp (°c)	Mould temp. (°c)	Vacuum time (min)	Shrinkage value (mm)
1	20	60	5	0.170105
2	20	70	10	0.234580
3	20	80	15	0.257925
4	25	60	10	0.281740
5	25	70	15	0.266970
6	25	80	5	0.162320
7	30	60	15	0.201785
8	30	70	5	0.191465
9	30	80	10	0.258070

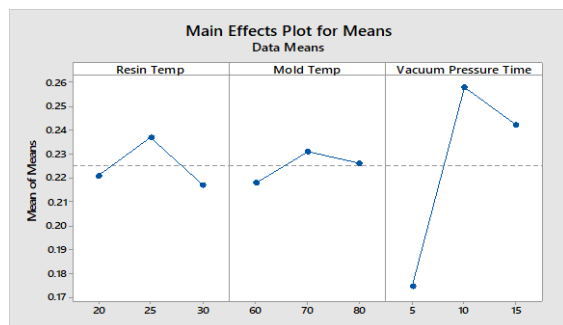Figure 2 Section B the main effects plot for SN ratios.

Figure 3 Section B the main effect plot for means.

Table 3 and 4 show the response table for signal to noise ratio and means. The values of Delta are the difference between maximum and minimum average of SN ratio for the factor.

3.2 Shrinkage comparison

Figure 4 shows the predicted shrinkage value by using the optimize parameter condition is 0.159 mm and default is 0.336 mm. That means the improvement of shrinkage is 52.4 percent.

4. CONCLUSION

In conclusion, the optimum parameter condition for vacuum casting process is 30°C for resin temperature, 60°C for mould temperature and 5 min for vacuum pressure time. Vacuum pressure time have the most significant effect compare to the mould and resin temperature on the dimension accuracy of the part.

Table 3 Section B response table for S/N ratios.

Level	Resin temperature	Mould temparature	Vacuum time
1	13.25	13.43	15.18
2	12.76	12.81	11.79
3	13.34	13.11	12.38
Delta	0.59	0.62	3.39
Rank	3	2	1

Table 4 Section B response table for means.

Level	Resin temperature	Mould temparature	Vacuum time
1	0.2179	0.2209	0.1746
2	0.2310	0.2370	0.2581
3	0.2261	0.2171	0.2422
Delta	0.0131	0.0199	0.0835
Rank	3	2	1
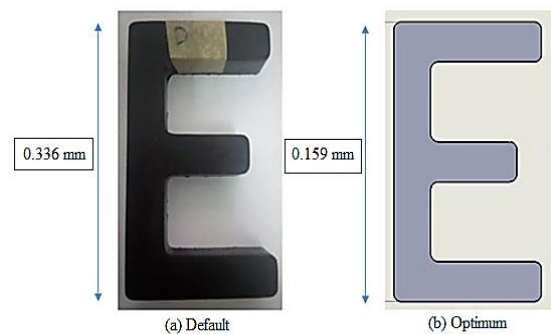
Figure 4 Shrinkage between default and optimum parameter.

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