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Desirability approach to Evaluate the Green Sand Casting Process Parameters

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ABSTRACT

The current study uses desirability functions to identify the green casting process parameters that are best for casting aluminium alloy 356. The permeability, pouring temperature, moisture content, and mould hardness of the casting process were among the variables that were optimized. The experiment is created using the L9 orthogonal array. Using analysis of variance (ANOVA), the responses—surface quality, hardness (on the Rockwell scale B), and micro-hardness (VHN)—are examined to establish the ideal casting process parameter settings. The ideal parameter setting is confirmed by the impact of casting process parameters on the various performance characteristics. The conformation test shows that the suggested strategy is effective.

Keywords -Green sand casting, Surface quality, Hardness ((Rockwell scale B) Micro-hardness (VHN), Desirability function.

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I. INTRODUCTION

Aluminum alloy have the potential to offer desirable properties, including low density, high specific strength, high specific stiffness, excellent wear resistance and controllable expansion coefficient, which make them attractive for numerous applications in aerospace, automobile, and military industries. Specifically the automotive industry has leaned greatly towards the use of aluminum alloys by virtue of their strength and low density. Given this, the potential for aluminum use in the fabrication of vehicle parts has greatly increased. Aluminum alloy 356.0 have typical applications in aircraft pump parts, automotive transmission cases, aircraft fittings and control parts, water-cooled cylinder blocks. However, there are limited studies devoted to the improvement of the casting process. Cartos S Santos et al presented the use of an artificial intelligence technique for the optimization of process parameters used in the continuous casting of steel [1]. Guharaja et al analyzed the various significant process parameters of the green sand casting process and optimized the process parameters by using Taguchi technique [2]. Ko-Ta Chiang et al presented the investigation on finding the optimal machining parameters setting for the die casting process of magnesium alloy using the grey-based fuzzy algorithm [3]. Vijian and Arunachalam optimized the squeeze casting process parameters using Taguchi analysis [4]. Himadri Chattopadhay reported the solidification time of simple shaped molds obtained by a lumped parameter model as well as by solving with a finite volume-based numerical computation [5]. Surekha et al presented the multi-objective optimization of green sand mould system using evolutionary algorithms, such as genetic algorithm (GA) and particle swarm optimization (PSO) [6]. Ko-Ta Chiang et al developed the modeling and analysis of the effects of processing parameters on the performance characteristics in the high pressure die casting process of Al–SI alloys [7]. Jiang Zheng et al optimized the high-pressure die-casting process parameters using artificial neural network [8]. Sushil Kumar et al established the optimization of green sand casting process parameters of a foundry by using Taguchi's method [9]. Jeong-Lian Wen et al studied the optimization of die casting conditions for wear properties of alloy AZ91D components using the Taguchi method and design of experiments analysis [10]. NoorulHaq et al demonstrated the optimization of CO_2 casting process parameters by using Taguchi's design of experiments method [11]. The intention of the present work is to optimize process parameters of the green sand casting of aluminum alloy 356 using desirability function.

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II. EXPERIMENTAL PROCEDURE

The commercially available aluminum alloy 356 was used for conducting these experiments, and its composition is listed in Table 1.The alloy was melted with the cupola furnace by burning of diesel with oxygen. Mold was prepared with different moisture content, mold hardness and permeability according to L_9 orthogonal array and shown in the Table 2. The pouring temperature were maintained at 600 ^{0}C to 750 ^{0} C. A gear blank pattern was used to mold the gear block as shown in the figure 1 with a moisture content range from 4 to 6 % , mold hardness 50 to 70 and pouring temperature 600 ^{0}C to 750 ^{0} C. Nine set of gear block were cast with different process parameters given in Table 3. The percentage of defects, surface quality and micro hardness of the parts casted under each set of process parameters was evaluated quantitatively. The green sand casting of aluminum alloy 356 as shown in the figure 1.

Fig 1. Green sand casting of Aluminum alloy 356 gear blanks

Table 1. Chemical composition of aluminum alloy 356

Cu- 0.25	Mg- 0.2 to 0.45	Mn- 0.35	Si- 6.5 to 7.5	Fe- 0.6
Zn- 0.35	Ti- 0.25	Bal - Al		

Fig 2. A Casted Aluminum alloy 356 gear blank

III. RESULTS AND DISCUSSION

The green sand casting of aluminum alloy 356 performance criteria selected for this study were based on performance characteristics such as surface quality in terms of surface roughness of the cast gear
blank, Rockwell hardness and micro hardness. The average surface roughness

Table 2. Casting process parameters and their levels

Sl. No	Parameter Designation	Process Parameters	Range	Level 1	Level 2	Level 3
1	A	Moisture content	4 – 6%	4%	5%	6%
2	B	Pouring Temperature	650 – 700° C	650° C	675° C	700° C
3	C	Permeability	19 – 44	19	30	44
4	D	Mould Hardness	50 – 70	50	60	70

value Ra (µm) was chosen to assess the surface finish quality of the casted gear blank with the help of Mitutoyosurfest SJ-

201 contact profilometer. The hardness of the cast gear blank was measured by using the Rockwell hardness testing machine

3.1 Multi-response optimization

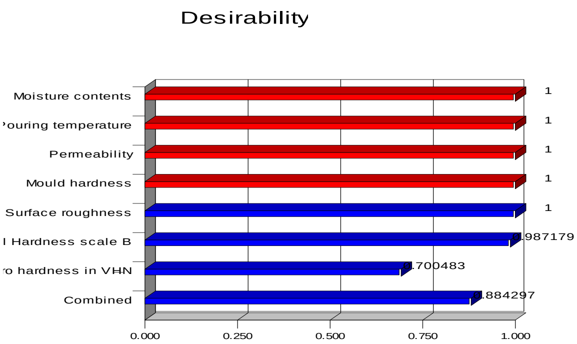
Selection of the optimal green sand casting process parameter combination for achieving improved process performance, e.g., surface roughness, hardness and micro hardness, is a challenging task in casting operation due to the presence of a large number of process variables and complicated stochastic process mechanism. Derringer and Suich [17] describe a multiple response method called desirability. It is an attractive method for industry for optimization of multiple quality characteristics problems. The method makes use of an objective function D(X), called the desirability function (utility transfer function) and transform an estimated response into a scale-free value (di) called desirability. The desirable range are from 0 to 1 (least to most desirable, respectively). A value of 1 represents the ideal case; 0 indicates that one or more responses are outside their acceptable limits. Composite desirability is the weighted geometric mean of the individual desirability for the responses.

The factor settings with maximum total desirability are considered to be the optimal parameter conditions. This combination has been evaluated with the help of Design Expert Software. Three responses, i.e., surface roughness, hardness and micro hardness, have been optimized simultaneously using developed models, i.e., Eqs.1, 2 and 3. In multi-response optimization, a measure of how the solution has satisfied the combined goals for all responses must be assured. The optimality solution is to evaluate the input process parameters in experiment range for maximizing hardness and minimizing surface defects shown in Fig. 3.

Surface roughness = +3.92 +1.03 * A + 1.02 * B+0.64 * C + 0.30 * C -0.054 * D (1)

Rockwell Hardness scale B = +26.06 +0.28 * A +0.94 * B +2.11 * C +2.61 * D **(2)**

Micro hardness in VHN =+69.62 -0.59 * A +0.14 * B -1.36 * C -0.32 * D (3)



Trial No.	**Control factor**				**Green sand casting process parameters and their levels**				**Surface Roughness in μm**	**Rockwell Hardness scale B**	**Micro hardness in VHN**
	A	**B**	**C**	**D**							
1	1	1	1	1	4%	650^0 C	19	50	6.56	32	67.5
2	1	1	2	2	4%	650^0 C	30	60	4.37	28	67.7
3	1	1	3	3	4%	650^0 C	44	70	3.94	19	71.9
4	2	2	1	2	5%	675^0 C	19	60	5.62	25	69
5	2	2	2	3	5%	675^0 C	30	70	2.37	23	69.9
6	2	2	3	1	5%	675^0 C	44	50	4.96	25.5	65.9
7	3	3	2	1	6%	700^0 C	30	50	2.64	24	72.8
8	3	3	3	2	6%	700^0 C	44	60	2.18	27	71.4
9	3	3	1	3	6%	700^0 C	19	70	2.68	31	70.5

Table 3. Design layout & Experimental results

Table 4 ANOVA table for surface roughness

Variable	**Sum of Square**	**Df**	**Mean SS**	**% C**
A-Moisture contents	9.75	2	4.875	49
B-Pouring temperature	5.82	2	2.91	29.25
C-Permeability	4.16	2	2.08	20.91
D-Mould hardness	0.022	2	0.011	0.11
Error	0.142	8	0.01775	0.71
Total	19.894	16		

IV. CONCLUSIONS

The application of green sand casting of aluminum alloy 356 in complicate shapes in aerospace and automobile parts manufacturing are considered to a challenging phenomenon to ascertain the best combination of input parameters so as to obtain better surface quality and high hardness. Further, the following inferences are deduced from this study.

- Green sand casting of aluminum alloy 356 studies were done and the mathematical models of the surface roughness, hardness (Rockwell scale B) and micro hardness (VHN) were carried out to correlate the dominant casting parameters, including the moisture contents, pouring temperature, permeability and mold hardness.
- The developed mathematical models of surface roughness, hardness (Rockwell scale B) and micro hardness (VHN) are properly well fitted with experimental values with a 95 % confidence interval.
- The main significant factors that affect the surface quality and hardness are moisture contents, pouring temperature and mold hardness whereas permeability remains insignificant.
- The higher pouring temperature offers lower the surface roughness value. On contrary, the hardness (Rockwell scale B) increases with increase in pouring temperature and mold hardness.

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