Diminishing the Casting Defects by using Optimization Technique

Tharoon T[1], Praveen rajha M[2], Santhosh N[3], Ranjith S N[4], Chelliah A[5]
[1, 2, 3, 4] UG Scholar, Department of Mechanical Engineering, SNS College of Technology, Coimbatore. [5]Assiant Professor, Department of Mechanical Engineering, SNS College of Technology, Coimbatore.

Abstract - The main intension of the paper is to improve the quality of casting products and to produce the casting products with zero defects by using various kind of optimization techniques such as Taguchi technique. The bonding strength of the sand is very essential to increase the quality of sand casting products. The taguchi analysis is done for optimizing the process parameters such as content of diethylene glycol content of dextrin and content of cellulose. The diethylene glycol, dextrin and cellulose are sand additives which are added to sand at different levels and remaining all adding agents such bentokole, bentonite, water content which are kept constant level in all type of testing sand. The experiments have been as per taguchi's L_{27} orthogonal array. Analysis of variance (ANOVA) performed to verify the sufficiency of the mathematical model. The Regression equation is predicted in account of process parameter, bonding strength. It can be noted that the bonding strength is increased with increase of content of cellulose in sand.

Key words: Diethylene, Glycol, Cellulose, Optimization, ANOVA, Taguchi

1. INTRODUCTION

Casting is a process of forming metallic products by melting the metal, pouring it into a cavity known as the mould, and allowing it to solidify. When it is removed from the mould it will be of the same shape as the mould. Almost any article may be cast with proper technique and design, and there is partially no limit as to the size and shape of the casting that may be made. The sand that is used to create the moulds is typically silica sand (SiO_2) that is mixed with a type of binder to help maintain the shape of the mould cavity. Using sand as the mould material offers several benefits to the casting process. Sand is very inexpensive and is resistant to high temperatures, allowing many metals to be cast that have high melting temperatures.

Additives are the materials generally added to thesand mixture to develop special properties in the mould and consequently in castings. Binders can be classified as inorganic and organic. Inorganic binders are clays (kaolinite, illite, and bentonites), cements, gypsum, and sodium silicate. Brown coal ashes etc. Organic binders include carbohydrate (starch, dextrin, and dextrose), molasses, various types of oils, pitches, natural resins (calophony, shellac) and synthetic resins (acrylic alkyd, polystyrene, melamine, urea formaldehyde, phenolic etc. The primary purpose of binders is to influence the bonding properties of sand of all the binders, dextrin is perhaps the best. It increases air-setting strength, toughness, and collapsibility and prevents. The quality of the sand that is used also greatly affects the quality of the casting and is usually described by the following five measures. Ability of the sand to maintain its shape is known as strength. Ability to allow venting of trapped gases through the sand, a higher permeability can reduce the porosity of the mould, but a lower permeability can result in a better surface finish. Permeability is determined by the size and shape of the sand grains is known as permeability, Ability to resist damage, such as cracking, from the heat of the molten metal is called thermal stability, Ability of the sand to collapse, or more accurately compress, during solidification of the casting. If the sand cannot compress, then the casting will not be able to shrink freely in the mould and can result in cracking is collapsibility and Ability of the sand to be reused for future sand moulds is known as reusability. Optimization is the act of obtaining the best result under given circumstances. The word 'optimum' is taken to mean 'maximum' or 'minimum' depending on the circumstances. In design, construction, and maintenance of any engineering system, engineers have to take many technological and managerial decisions at several stages. The ultimate goal of all such decisions is either to minimize the effort required or to maximize the desired benefit. Since the effort required or the benefit desired in any

practical situation can be expressed as a function of certain decision variables, so optimization can be defined as the process of finding the conditions that give the maximum or minimum value of a function. The optimum searching methods are also known as mathematical programming techniques and are generally studied as a part of operations research. Operations research is a branch of mathematics concerned with the application of scientific methods and techniques to decision making problems and with establishing the best or optimal solutions.

2. PROBLEM DEFINITION

In industry, the defects occur in sand casting due to improper of properties of sand such as insufficient bonding strength and improper mixing of sand additives. So improve the bonding strength by means of proper mixing of sand additives. This is remedy action for that kind of problem.

3. EXPERIMENTAL DETAILS

In the present investigation, casting sand (Green sand) is taken for testing. The other contents

Fig 1. Sand testing equipment (strength tester)

Such as bentokol, bentonite, water level and remaining items are added to the testing sand and they are kept in constant level in all kind of sand. Sand additives such as diethylene glycol, dextrin, and cellulose are added to all kind of sand but in different levels of composition like 27 various composition tabulated in table 1. The main intension of this experiment is to peruse highest bonding strength at which level of additives composition such as diethylene glycol, dextrin and cellulose. After, adding of various chemical composition such as diethylene glycol, dextrin and cellulose sands are tested by the sand testing equipment's like strength tester. The values are tabulated in table 2. The equipment's are shown in Fig 1.

4. DESIGN OF EXPERIMENTS

DOE is a powerful tool for identifying a set of process factors (parameters) which are most important to the process and then determine at what levels these factors must be kept to optimize the response (or quality characteristic) of interest. It derives its power from the fact that it helps maximize the information gained from a given number of experiments whilst using a minimum of resources. This is obtained through factorial design, a structured approach based on statistical methods that supports the simultaneous changing of more than one factor at a time. For developing models on the basis of experimental data, careful planning of experimentation is essential. The factors considered for the experimentation and analysis are content of diethylene glycol (g), content of Dextrin (g), and content of Cellulose (g). The design of experiments have major effect on the number of experiments needed. Therefore it is essential to have a well-designed set of experiments. Design of experiments (DOE) is a systematic method, to determine the relationship between factors affecting a process and the output of that process. In this paper, the factors are considered such as content of diethylene glycol (g), content of Dextrin (g), and content of Cellulose (g) in sand mixing.

4.1 Experimental Parameters and Levels

Table 1. Parameters and levels

S.No	Parameters	Unit	Symbol	Levels in Taguchi Design		
				Level I (low)	Level II (Medium)	Level III (High)
1.	Content of Diethylene Glycol	grams	DG	100	200	300
2.	Content of Dextrin	grams	DT	150	250	350
3.	Content of Cellulose	grams	CE	100	250	450

The content of diethylene glycol (g), Dextrin (g) and Cellulose (g) improve the bonding strength of sand, So the parameters are taken for the current investigation are content of diethylene glycol (g), content of Dextrin (g), and content of Cellulose (g). The parameters and levels set at three different levels, namely low, medium and high as shown in Table 1.

4.2 Taguchi L_{27} Orthogonal array

The Taguchi method has been proposed to overcome these limitations by simplifying and standardizing the fractional factorial design. The methodology involves identification of controllable

Table 2. Uncoded values

Test No	Uncoded Values			Bonding Strength (kg/cm^2)
	DE (g)	DT (g)	CE (g)	
1.	100	150	100	920
2.	100	150	250	950
3.	100	150	450	970
4.	100	250	100	1090
5.	100	250	250	1075
6.	100	250	450	1080
7.	100	350	100	1350
8.	100	350	250	1380
9.	100	350	450	1400
10.	200	150	100	1080
11.	200	150	250	1070
12.	200	150	450	1070
13.	200	250	100	1300
14.	200	250	250	1275
15.	200	250	450	1250
16.	200	350	100	960
17.	200	350	250	970
18.	200	350	450	980
19.	300	150	100	1260
20.	300	150	250	1200
21.	300	150	450	1280
22.	300	250	100	908
23.	300	250	250	925
24.	300	250	450	920
25.	300	350	100	1050
26.	300	350	250	1025
27.	300	350	450	1050

uncontrollable parameters and the establishment of a series of experiments to find out the optimum combination of the parameters which has the greatest influence on the performance and the least variation from the target of the design. Based on this, Taguchi L_{27} orthogonal array has been selected each having a combination of different levels of factors, as shown in Table 2. The variables are coded by taking into account level of content of diethylene glycol (g), Dextrin (g) and Cellulose (g).

5. RESULTS AND DISCUSSION

5.1 Determination of the Regression model and Evaluation of Statistical

The Regression equation, ANOVA and Graph is generated by using Minitab software. The regression equation is give the relationship among the content of Diethylene glycol (g), content of Dextrin (g), and content of Cellulose (g).

5.2 Regression Analysis for Bonding strength (Response)

The regression equation for bonding strength is given by,

Bonding Strength (Kg/cm^2) = 846 + 0.332 DE + 0.203 DT + 1.02 CE

Table 3. Regression analysis for bonding strength

Predictor	Coefficient	SE Coefficient	T	P
Constant	846.43	26.29	32.19	0.000
DE	0.33167	0.07231	4.59	0.000
DT	0.20278	0.07231	2.80	0.010
CE	1.02177	0.04118	24.81	0.000

S=30.6775	R^2= 96.6%	R^2 (adj)= 96.1%

The goodness of fit was clarified by the determination coefficient (R^2).In this study, the value of determination coefficient is 0.966 which is indicated that 4% of the total variations were not explained by the regression model. The adjusted determination coefficient is 0.982. So we noticed that the adjusted determination coefficient is closer to the determination coefficient which means a good correlation between the responses and the experimental results in response as bonding strength.

5.3 ANOVA Analysis for bonding strength (Response)

ANOVA was performed by the Minitab Software. Which give the effective values. The percentage of contribution was calculated. From ANOVA table we understand the content of Cellulose plays an important role in bonding strength of sand because its percentage of contribution is 93.40%. The secondary contribution factor is content of diethylene glycol and its percentage of contribution factor is 3.20%. Third contribution factor is content of dextrin and its percentage of contribution is 1.49%.

Table 4. ANOVA table for bonding strength

Sources	DOF	SS	MS	F	P	Percentage of Contribution
DE	2	19910	9953	21.85	0.012	3.20
DT	2	9286	4643	10.19	0.022	1.49
CE	2	585239	292629	642.13	0.000	93.40
Error	18	8203	456			1.37
Total	26	**622638**				**100**

5.4 Taguchi Analysis for bonding strength (Response)

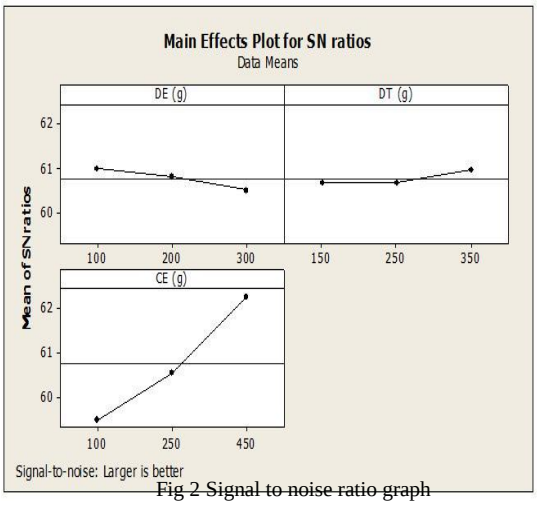

Fig 2 Signal to noise ratio graph

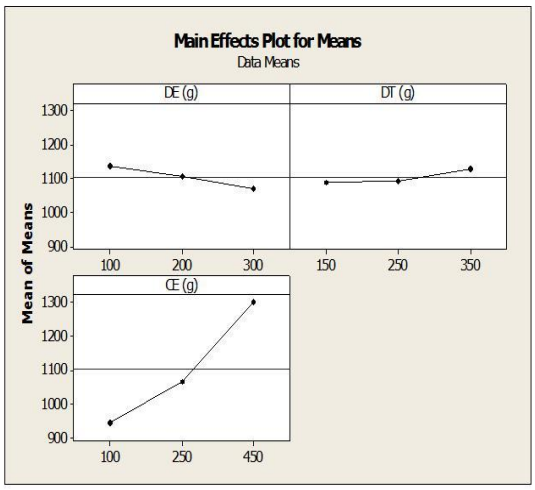

Fig 3. Mean plot graph

Response Table for Signal to Noise Ratios Larger is better

Table 5. Taguchi analysis for bonding strength (SN ratio)

Level	DE	DT	CE
1	60.99	60.68	59.50
2	60.82	60.68	60.55
3	60.50	60.95	62.26
Delta	0.49	0.27	2.76
Rank	2	3	1

Table 6. Taguchi analysis for bonding strength (Mean)

Level	DE	DT	CE
1	1135	1088.9	944.8
2	1106	1091.4	1065.6
3	1068.7	1129.4	1299.4
Delta	66.3	40.6	354.7
Rank	2	3	1

Taguchi analysis is done as above we got signal to noise ratio graph and mean plot graph as shown in the figure. From which a major influencing factor is obtained.

5.5 Normal Probability plot Graph for bonding strength (Response)

The normal probability plot graph is obtained by using the regression equation and the experimental values. It is a graphical representation for assessing whether data set is normally distributed or not. The graph should give approximately in a line. So the errors are distributed normally.

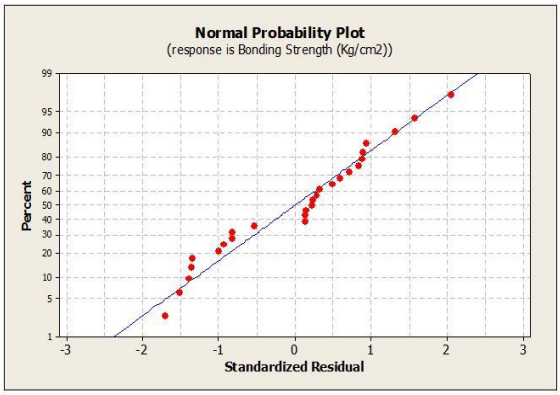

Fig 4. Normal probability plot

5.6. Confirmation Test

Table 7. Confirmation test for bonding strength

Trial No	DE	DT	CE	Experimental Bonding strength	Predicated Bonding strength	% Error
1.	150	300	450	1395	1400	0.358
2.	350	550	550	1652	1650	0.122
3.	450	700	650	1848	1850	0.11

The L_{27} array were conducted which means 27 experiments were conducted from which the percentage of error is calculated and tabulated at different conditions such as content of diethylene glycol, content of dextrin, content of cellulose for bonding strength (response).

6. CONCLUSION

In this paper, Taguchi L_{27} Orthogonal is used to optimize the process parameter. The following conclusions are done by this experiment,

- In Regression analysis, the adjusted determination coefficient is very closer to the determination coefficient so evaluation of bonding strength of sand is done by effectively and efficiently.

- Content of cellulose is found to be the first influencing factor on bonding strength of sand.
- The second influencing factor is content of diethylene glycol on bonding strength of sand.
- The third influencing factor is content of dextrin on bonding strength of sand.
- The normal probability plot graph is obtained in the form of straight line so the errors are distributed normally.

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