OPTIMIZATION OF PROCESS PARAMETERS OF CO_2 MOULDING PROCESS FOR BETTER KNOCKOUT PROPERTY

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ABSTRACT

CO_2 moulding process, though known for its superior mould hardness and amenable for casting high density alloys, is suffering with drawback of poor collapsibility. In this paper it is attempted to optimize the process parameters of CO2 moulding process, through Taguchi approach, for better knockout property of mould.L8 orthogonal array is selected as experimental plan. S/N analysis is made and ANOVA is performed to decide the contribution of factors and F-test is conducted to discriminate significant factors from others. It is observed that factors namely percentage of sodium silicate and percentage of coal dust have significant bearing on the collapsibility

Key Words: *CO_2 moulding, collapsibility, Taguchi approach*

I. INTRODUCTION

Even after the evolution of several moulding processes for the preparation casting cavities sand moulding has the major share of production of mould cavities of castings. Apart from the metal being cast and casting conditions the type of mould material also has a significant bearing on the quality of the casting[6].One need not over emphasize the importance of silicate bonded CO_2 moulding process among the sand casting processes. The development of the Carbon dioxide (CO_2) process of moulding and core making about thirty years ago marked the advent of an epoch making era in the foundry practice. The method has not only cured the headache of foundry men caused by the need for greater skill and care during moulding and baking it has also removed serious bottle necks before the management in planning a regular and streamlined production of castings at a low rejection rate[7]. The process can serve as an inexpensive substitute for dry sand moulding where close tolerances are specified [8]. Owing to its high mould hardness CO2 process is widely used for casting the various metals and alloys and especially high-density alloys like steels [9, 10]. In view of its overwhelming advantages and versatility, CO_2 process has proved successful for large and diversified applications such as valves pumps compressors, machine tools, wheel castings, Diesel engine components and railway components.

1.1 Strength in Silicate Bonded Sands

Since its introduction, the sodium silicate process of mold and core making has undergone several modifications, mainly with the hardening agents. The earliest hardener used CO_2 gas is still in use [1] Formation of silica gel is the essence of strength development in CO_2 moulds. Sarkar [2] in his book provides a lengthy description of the relation between silicagel formation and bond development. The physico-chemical changes involved in the process of strength development in sand bonded with sodium silicate are at best vaguely understood. The individual grains of sand covered with a thin coating of sodium silicate are made to tie with each other in the process of mold of core making. Experimental work suggests that a molecule of silica should be associated with approximately six molecules of water for maximum strength properties thus, in all probability over gassing results in the loss of water from the gel.

1.2 Significance of Present Investigation

It is necessary to build moulds of good quality for obtaining sound and defect free castings. Considerable amount of literature on strength of sands bonded with sodium silicate is mostly directed towards control on a day-to-day basis, rather than towards understanding the basic phenomena involved [1] to have the best possible mould properties. A stringent control is to be exercised over the process parameters of CO_2 moulding, in many instances it is difficult to perceive the trend of change of mould properties with respect to change in the process parameter values [11]. Hence there is a need to optimize the process parameters for the desired characteristic of mould made of CO_2 moulding process. Few of the earlier investigations [3] attempted in this direction but not considered the aspect of knock out property i.e good collapsibility which is of prime concern in CO_2 moulds and hence the present investigation.

Taguchi method is a well established statistical technique that aids in formulating a suitable experimental design matrix [12, 13]. Further it helps in systematic analysis of the results and in turn arriving at meaningful conclusion with minimum amount of experimentation

1.3 Response Characteristics

The response characteristic considered in the present study is knockout property i.e collapsibility. The main problem with CO_2 moulds is difficulty in knockout due to poor collapsibility. In actual practice of casting the component any moulding material is subjected to heating while absorbing heat from pored metal and slowly gets cooled while transferring heat to surrounding medium. Strength of the mould after heating and cooling cycle is called retained strength. Retained strength is a measure of collapsibility of the mould [4]. Quality characteristic for retained strength (collapsibility) is "Smaller the better". Retained strength after standard specimens are heated to a temperature of 1000 C for a period of 10 minutes and cooled to room temperature is a measure of collapsibility [4]

1.4 Taguchi's philosophy

Traditional statistical methods use the mean to compare results. Using the standard deviation one may determine whether the difference between two groups is significant or not. Taguchi method altogether uses a different term Signal to Noise ratio(S/N ratio) to compare the results[5]. Goal of Taguchi method is to choose control factors that provides not only the desired result but also to direct a process that is less sensitive to noise. Although noise can't be eliminated its effect can be minimized

S/N ratio = -10 log (MSD)

MSD=Mean square deviation of the results of replications of an experimental trial combinations

II. OBJECTIVE

This investigation is aimed at optimizing the process parameters of CO_2 moulding process for better knockout property (Collapsibility) of the mould.

III. METHODOLOGY

- Identifying the process parameters and their levels
- Selection of a suitable experimental plan
- Building up of necessary gassing arrangement
- Conducting of experiments as per the selected experimental plan
- Response graph for each of the process parameters
- Deciding significant parameters based on ANOVA and F-test
- Deciding the Optimum condition and result at optimum condition
- Confirmation trials

3.1 Identifying the Process Parameters and Their Levels

The process parameters considered are percentage of sodium silicate, quantity of Co2 gas (gassing time), mixing time of the sand mix in the mixer and percentage of coal dust Usual percentage of sodium silicates used in the process is 3% to 6%[1] .Now the levels of sodium silicate considered are 4% and 6% with respect to the quantity of silica sand. Main responsible agent for the formation of silica gel is CO2 gas. Under gassed Co2 mould result in to inferior mould hardness and other properties. At the same time over gassing also leads to reduction of the strengths of the mould Chemical requirements of CO2 gas for reacting with Na2O of sodium silicate is estimated to be 10kg per 100 kg of silicate used However in shop floor conditions a quantity up to 40 kg per 100 kg of silicate should be considered ideal[4] These levels of quantity of CO2 gas are appropriately converted in to gassing time and hence quantity of CO2 gas factor is termed as gassing time in the foregoing sections of this article. Time of mixing of sand and sodium silicate place an important role for uniform coating of sodium silicate over sand grains and in turn the ability of formation of silica gel bond among sand grains. Too high a mixing time overheats the sand mix and affects bonding properties, generally the mixing times employed are 5 to 10 minutes [4]. In the present work two levels of mixing time 5minutes and 10 minutes are considered .Coal dust is one of the important break down agent that imparts ease of collapsibility to the mould Maximum of 2% coal dust is generally used [51].The two levels of coal dust considered are 0% and 2% Process parameters, their designation and their levels are shown in table-1

3.2 Selection of a Suitable Experimental Plan

Four factors are considered at two levels, further effect of two interactions between sodium silicate, gassing time and sodium silicate, mixing time are planned to be studied

The total number of degrees of freedom is 6(N=4(1) +2(1) =6)

Hence an L8 orthogonal array having seven degrees of freedom is suitable for the purpose[5]. Experimental plan (L8 array) along with actual values of factor levels is show in Table-2

Table-1 Description of Factor & Levels

S.NO	Factor name	Level-1	Level-2
1	Percentage of Sodium silicate(SS)	4%	6%
2	Gassing time in seconds(GT)	13 sec	30sec
3	Mixing time in minutes (MT)	5 minutes	10 minutes
4	Percentage of coal dust(CD)	0%0	2%

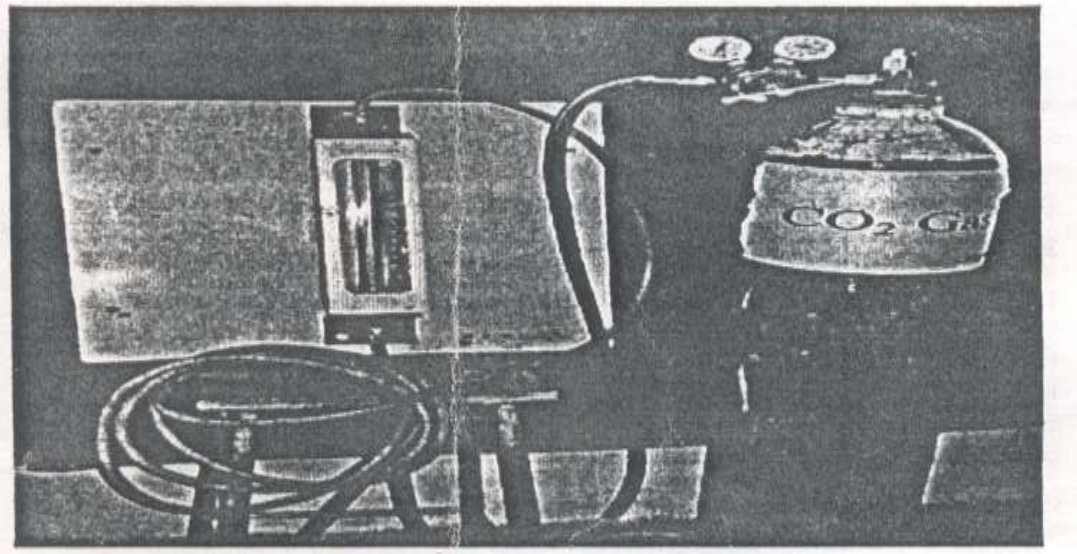

Fig-1Gassing arrangement setup

Table-2:L8 Orthogonal Array with Actual Values of Factor Levels

TrialNo	SS(1)(1)	GT(2)(seconds)	SSXGT	Mt(3) minutes	SSXMT	Unused Column	CD(7)
1	4%	13	1	5	1		0%
2	4%	13	1	10	2		2%
3	4%	30	2	5	2		2%
4	4%	30	2	10	1		0%
5	6%	13	2	5	1		2%
6	6%	13	2	10	2		0%
7	6%	30	1	5	2		0%
8	6%	30	1	10	1		2%

3.3 Experimental Setup

Exact amount of CO2 gas is required to be supplied to molds. To facilitate this, a simple experimental set up is built .Apart from monitoring the pressure of CO2 gas the exact quantity of gas supplied to the mould can be metered with the help of a Rota meter attachment to the cylinder. Gassing arrangement setup shown in figure 1 consists of i) CO2 gas cylinder ii) Rota meter iii) Nozzle iv) Pressure gauge v) Hose pipe

3.4 Conducting Of Experiments as Per the Selected Experimental Plan

Sand mixes are prepared as per the experimental plan shown in Table-2. In the total mixing time initially dry mixing is carried for one minute and remaining mixing time is continued with the addition of sodium silicate. Standard sand specimens of 2’’ X 2” specimen are prepared from the prepared mix in a split specimen tube. The specimens are gassed using gassing arrangement. Retained strength after exposing the sand specimen to 1000 C for 10 minutes and cooling to room temperature (Collapsibility) are determined and the results are tabulated in Table-4.Each experiment is replicated thrice.

Table-3

Trialno	Collapsibility (Retained strength) (kg/sq.cm)			Average	S/N ratio
	R1	R2	R3		
1	2.08	2.48	2.36	2.306	-7.283
2	2.68	3.12	2.92	2.906	-9.285
3	0.48	0.48	0.40	0.453	6.841
4	4.24	4.44	4.40	4.36	-12.792
5	2.84	3.68	3.44	3.253	-10.295
6	5.56	8.58	6.39	6.843	-16.854
7	4.72	6.28	5.46	5.486	-14.843
8	1.36	4.32	3.66	3.113	-10.532

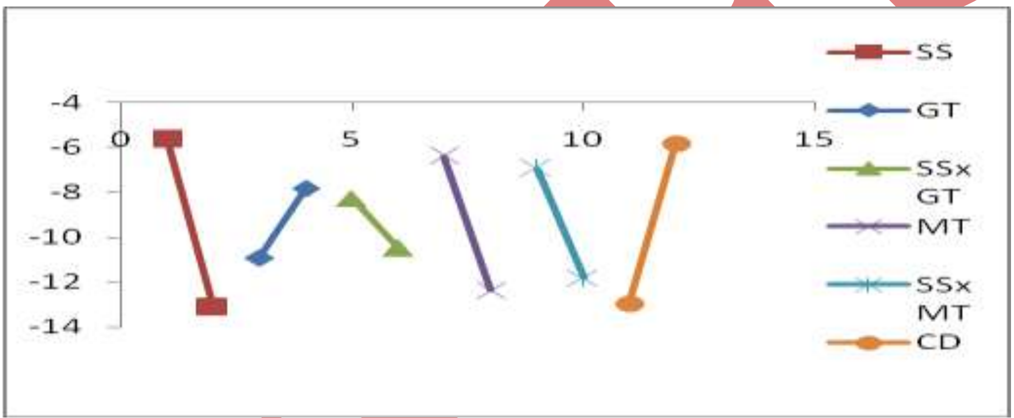

Fig-2 Response Graphs

IV. RESULTS AND DISCUSSION

Average values and S/N values of results of replications of each trial combination are found out and the results are shown in Table-3. Response graphs are drawn to determine the effect of each factor on the response characteristic. From fig-2 it can be observed that percentage of sodium silicate and cold dust are the important factors to be controlled to have higher collapsibility i.e lower retained strength. Whatever may be the quality characteristic the optimum condition of factors is based on the maximum value of S/N ratio From the response graphs the optimum condition is observed to be 4% SS,30 sec gassing time,(SS X GT) Second level , 5 minutes mixing time(SS X Mt) First level, 2% CD.

Table-4 ANOVA

Factor	Dof	SS	Variance	F-ratio	Percentage Contribution
SS	1	112.553	112.553	19.704	30.66
GT	1	19.186	19.186	3.358	5.23
1 * 2	1	9.78	9.78	1512	2.67
MT	1	71.288	71.288	12.48	19.4

1 * 4	1	46.991	46.991	8.226	12.8
CD	1	101.548	101.548	17.777	27.67
Error	1	5.711	5.711		1.57
Total	7	367.061			100

Table-5 Optimum Condition

	Level of Description	Level Contribution
SS	4%[2]	3.75
GT	30 Sec[2]	1.548
SSXGT	[2]	1.105
MT	5 min [1]	2.985
SSXMT	[1]	2.423
CD	2% [2]	3.562
		15.372

Though effect of each factor on the collapsibility can be determined using response graphs but the significance of various factors and interactions can be ascertained through Analysis of variance (ANOVA) and F-test. Analysis of variance of the experiment is given in Table-4

4.1 F-Test

This test determines significance of each factor on the response characteristic from the statistical F-table. F-ratio corresponding to degrees of freedom of factor ‘1’ and error degrees of freedom ’1’ is 1.6 Hence all the factors including SS X MT interaction are significant. Only (SSXGt) interaction is insignificant Out of all the significant factors sodium silicate and percentage of coal dust have higher percentage of contribution.(SS X MT) interaction though significant contribution is almost zero

4.2 Optimum Combination

The optimum combination of factors and it’s contribution towards the optimum value of collapsibility (Retained strength) is given in Table-5

Result at optimum condition

$Y=T+[\overline{SS1}-\bar{T}]+[\overline{CD2}-\bar{T}]++[\overline{GT2}-\bar{T}]+[\overline{MT2}-\bar{T}]=-9.381+3.75+3.562+1.548+2.985+2.423$

S/N value=4.887

Actual value=Y_{opi}=0.569 kg/sq.cm

Range of expected result at optimum condition

C.1=sqr root [F(1,n2)=Ve/Ne]

At a confidence level of 90% C.I=+/- 2.39

Range of result(S/N values)=3.062 to 8.38

Range of result (Actual values)=0.66 to 0.38 kg/sq.cm

4.3 Confirmation Test

Confirmation test is conducted at optimum condition obtained. The result obtained is 0.48 kg/sq.cm which is well within the confidence interval of the predicted result.

V. CONCLUSIONS

Taguchi method can be successfully used for optimizing the process parameters of the CO2 moulding process The optimum level of process parameters for maximizing the collapsibility i.e minimizing the retained strength are 4% sodium silicate . 30 sec gassing time,5 minutes mixing time and 2% CD, Out of the two interactions considered only (SS X Mt) is significant Percentage of Sodium silicate and percentage of coal dust has a significant bearing on the collapsibility .The result of the confirmation test is within the confidence interval of the predicted result.

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