Process Parameter Optimization of Co2 Moulding Sand Using Response Surface Methodology

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Abstract— **In this paper, attempts are made to optimize process parameters in CO2 Moulding sand of co2 casting process using response surface methodology. Three independent process parameters AFS number of moulding sand, percentage of sodium silicate and percentage of dextrin powder are selected to assess the co2 moulding process process performance in terms of sand permeability number and dry compression strength (kg/cm^2).To plan and analyse the experiments, Response Surface Methodology (RSM) employing rotatable central composite design (CCD) is used. The relation between input process parameters and response variables is studied with the help of contour plots obtained by the use of RSM. For each response, Analysis of Variance (ANOVA) is done to study the influence of each process parameter. ANOVA is carried out within 95% of confidence level (p-value ≤ 0.05). It is found out that AFS Number and percentage of sodium silicate are significant parameters for dry compression strength. It is also observed that the linear terms, AFS number and percentage of sodium silicate along with quadratic term percentage of sodium silicate × percentage of sodium silicate are significant to permeability.**

Index Terms— **Co2 moulding, dry compression strength, permeability.**

I. INTRODUCTION

Mould properties such as permeability, DCS (dry compression strength), DSS (dry shear strength) have to be dealt with utmost importance in order to obtain a good quality mould. If these properties are found below the required values, then it will in turn give a low quality mould resulting in poor casting quality. The process parameters selected were AFS number, Yellow dextrin content and Sodium silicate content. Yellow dextrin is used to improve the binding strength between sand particles in a mould. Sodium silicate mixed in dry sand reacts with CO2 passed through the mould. CO2 reacts with sodium silicate and forms silica gel and in turn it hardens and imparts strength to the mould [1].
Permeability number should be above 200, DCS above 6.5 kg/cm^2, after making mould pouring might be done at different times. So the mould strength should remain in limits until the pouring of metal occurs. Also mould should withstand while pouring and solidification too. So in order to find out the optimum parameters determining the properties which are applicable for the mould till pouring this experiment is carried out. [2]

Carbon Dioxide Moulding Process

In CO2 moulding process, mixture of moulding sand with sodium silicate is used .The mixture is loosely rammed in the mould box around the pattern. Carbon dioxide gas is passing through the mould. Carbon dioxide is reacted with sodium silicate and hence silica gel is formed [3].

$$Na_2SiO_3 + CO2 \text{ ----- } Na_2CO3 + SiO_2 \text{ ----- (1)}$$

Silica gel is a new chemical compound that is found in reactions caused by various hardeners. This new product is called gel and in the present case it is “silica gel” .In silica gel the dispersed phase is silica. during CO2 moulding process gel formation can be visualized as a Water solution of sodium silicate reacting with CO2 produce mono silica acid and sodium carbonate [4].

Importance of present investigation

Carbon dioxide moulds are useful for pouring alloys of high density like steel .Hence the requirement of mould in high hardness, strength and permeability. High hardness of mould resist penetration of hot liquid metal, usually of high density, in to mould wall. So hardness of mould should be higher the better. As well as strength and sand permeability is equal importance like hardness, to prevent defect from casting. By varying different parameters of moulding process the properties of mould will alter. So it is necessary to find out a set of values of parameters of the process that will give us the maximize strength and better permeability [5, 6].

II. Experimental work

The design and optimization of experiments is carried out by using RSM employing rotatable central composite design. A total of 20 experiments are carried out which include eight factorial runs, six axial runs and six centre runs.

Table 1: Process parameters and their respective levels

Levels (coded variables)	Factors		
	AFS (A)	% of sodium silicate (B)	% of yellow dextrin (C)
-1	39	3.5	0
0	42	4.5	0.5
1	45	5.5	1

Mixing of sand will be done uniformly. After which the specimens will be made with the help of a split specimen tube. With the help of a sand rammer, the sand will be rammed by three strokes. Then CO2 gas will be passed through specimen for reaction with sodium silicate to occur. After which the specimens will be tested using a permeability meter for finding permeability number, and with a universal strength machine to find out DCS in kg/cm2. The values are tabulated and are optimized with the help of MINITAB software.

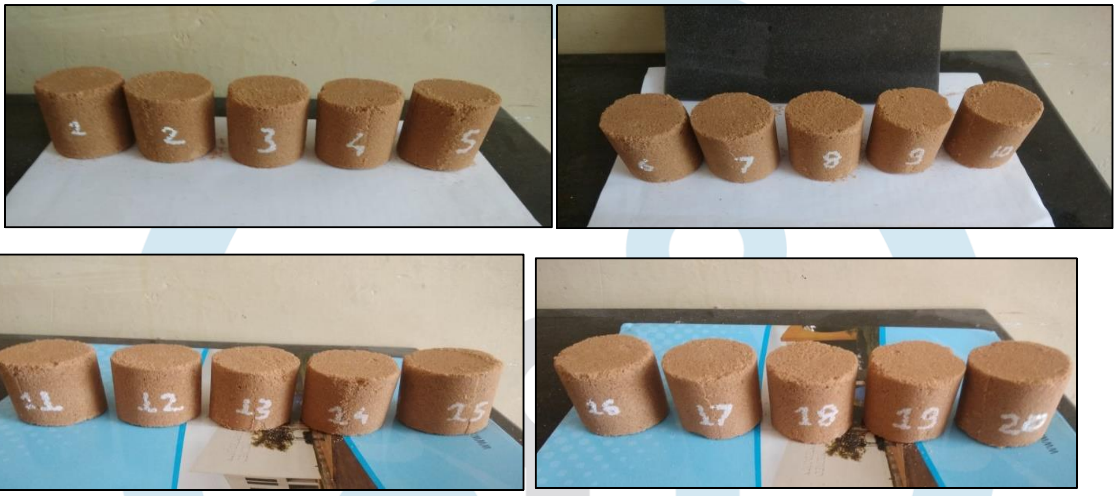

Fig: 4.3 sand specimen for testing

III. Results and Discussion

The experiments are performed as per DoE based on RSM using MINITAB-17 software. The values of dry compression strength and permeability are measured using sand testing UTM and permeability meter. The results of experiments are shown in Table 2. Below figure shows the experimental set up.

Fig: 4.4 Permeability Meter

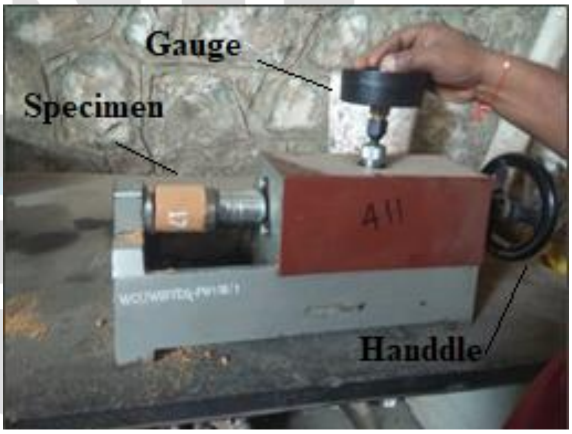

Fig 4.5 Universal Sand Strength Machine

Table 2: Results of experiments

Std Order	Input Parameter			Response Parameter	
	AFS (A)	% of sodium silicate (B)	% of yellow dextrin (C)	DCS (kg/cm^2)	Permeability
1	39	3.5	0	7.95	224.47
2	45	3.5	0	9.5	245
3	39	5.5	0	6.6	254.3
4	45	5.5	0	6.26	275
5	39	3.5	1	10.9	228.16
6	45	3.5	1	10.3	243.8
7	39	5.5	1	7.1	248.09
8	45	5.5	1	10.3	242.4
9	36.95	4.5	0.5	11.45	211
10	47	4.5	0.5	12.7	232.4
11	42	2.81	0.5	10.3	241.33
12	42	6.18	0.5	11.6	226.4
13	42	4.5	-0.34	10.35	242.8
14	42	4.5	1.34	6.41	260.12
15	42	4.5	0.5	6.72	255.7
16	42	4.5	0.5	6.13	252.6
17	42	4.5	0.5	10.2	243.2
18	42	4.5	0.5	10.25	242.3
19	42	4.5	0.5	11.15	235
20	42	4.5	0.5	5.7	262.2

IV. Analysis of variance (ANOVA)

Analysis of variance is done to find out the most significant parameter. ANOVA is carried out at 95% significance level. ANOVA for material removal rate is shown in Table 3. It is seen that peak current is most significant parameters for material removal rate followed by pulse on time as their respective p-values are less than 0.05. ANOVA for average surface roughness is shown in Table 3. It can be seen that the AFS Number and percentage of sodium silicate and percentage of dextrin powder all are significant to DCS along with the quadratic term AFS* AFS, dextrin 8 dextrin powder. Whereas AFS Number and percentage of sodium silicate are significant to permeability along with the quadratic term AFS* AFS.

Table 3: ANOVA for DCS and Permeabilty

Source	Degree of freedom	DCS		Permeability	
		F-Value	P-Value	F-Value	P-Value
AFS	1	303.44	0.000	24.31	0.001
% of Dextrin	1	76.27	0.002	2.86	0.122
% of sodium silicate	1	83.64	0.000	27.81	0.000
AFS*AFS	1	31.38	0.001	11.4	0.007
Dextrin*Dextrin	1	14.89	0.003	0.88	0.37
sodium silicate*sodium silicate	1	0.26	0.621	5.71	0.038
AFS*Dextrin	1	23.41	0.001	0.07	0.795
AFS*% of sodium silicate	1	7.48	0.021	4.22	0.073
Dextrin*% of sodium silicate	1	0.86	0.376	0.13	0.725
Error	10				
Total	19				
DCS- S = 2.72551 R-sq= 98.21% R-sq (adj) = 96.59% R-sq (pred) = 85.33%					
Permeability-S = 14.9673 R-sq= 88.24% R-sq (adj) = 77.66% R-sq (pred) = 11.25%					

V. Counter Plot for DCS and Permeability

The contour plots of dry compression strength are shown in Fig. 2. AFS number and percentage of dextrin powder are directly proportional to DCS Thus higher values of dry compression strength can be achieved at higher values of AFS number, and percentage of dextrin powder and nominal values of percentage of sodium silicate. Counter plots shows the optimum region for the maximize dry compression strength is AFS 43-46,Dextrin 0.5-1.2 and percentage of sodium silicate 4.2-6.0.

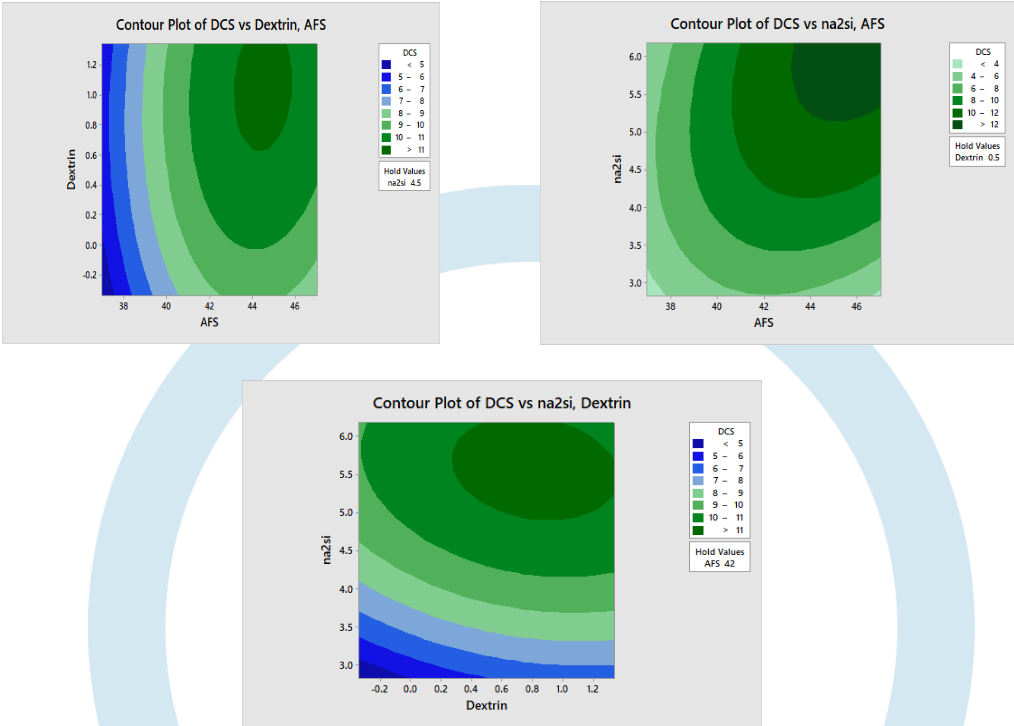

Figure 2: Contour plots of Dry Compression Strength

The contour plots of Sand permeability number are shown in Fig.3. From the plots it can be seen that and pulse on time have adverse effect on surface finish i.e. the surface roughness increases with increase in peak current and pulse on time whereas surface roughness decreases with increase in gap voltage.

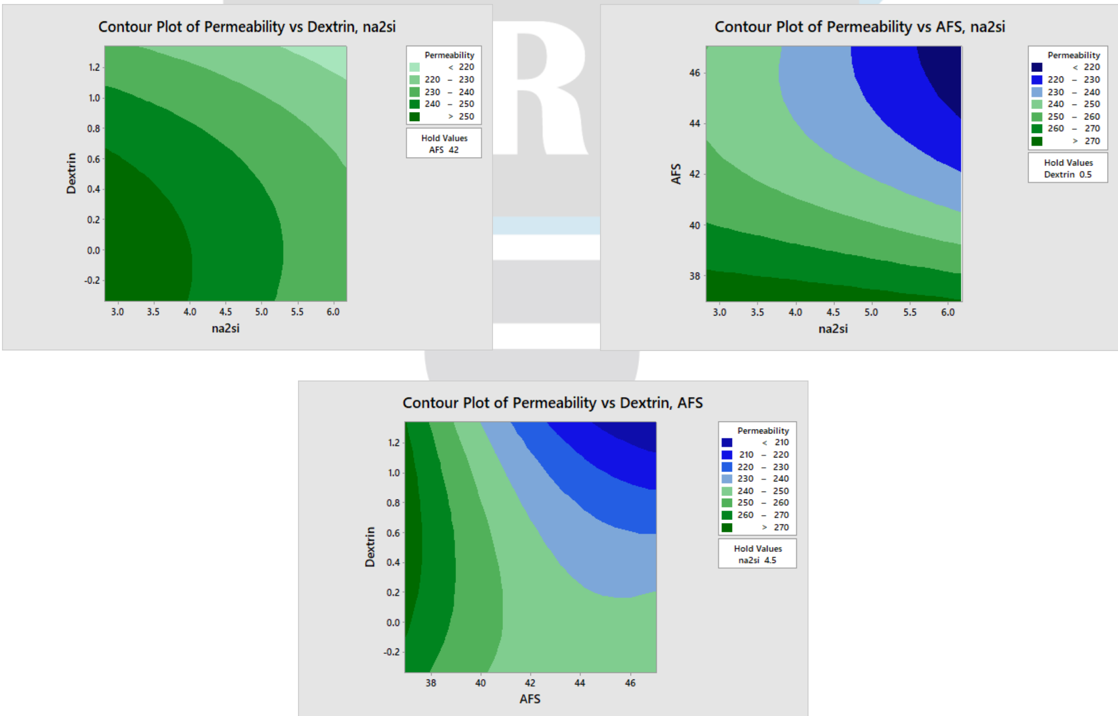

Figure 3: Contour plots of permeability

VI. CONCLUSIONS

a) Optimum setting level of selected process parameters are obtained by response surface methodology for the response variable dry compression strength and sand permeability number. AFS number 42, percentage of sodium silicate 4.80%, percentage of dextrin powder 0.5%.

b) It is observed that as we increases AFS number and percentage of dextrin powder permeability get reduces while strength get increases while we increases the percentage of sodium silicate higher permeability number goes high and dry compression strength goes lower side.

c) From the above experimentation we get optimum setting as per our response surface requirement permeability is nominal (240-250) and maximum dry compression strength (10.73kg/cm^2).

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