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Multi-response optimization of quality characteristics of co2 moulding sand using taguchi method

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Abstract
Mould properties and its control is a section in foundry industry that has to be dealt with prior importance during the making of moulds. The property of the mould sand and mould plays a key role in determining the quality of the casting. There are several important properties associated with these such as moisture content, permeability, compatibility, combustibility, mould hardness, tensile strength, shear strength, transverse strength, compression strength etc. This work is aimed at optimizing the
CO_2 sand mould properties using Taguchi method with the help of MINITAB software. A multi-response optimization method is intended to be followed. For that three input parameters and three output parameter are taken for CO_2 sand. All the three output parameters will be optimized individually. The input process parameters selected for CO_2 sand are AFS (Average Fineness of Sand) number, percentage of yellow dextrin content and percentage of sodium silicate content at three levels, and the output parameters selected are permeability, dry compression strength (DCS) and dry shear strength (DSS). An L9 orthogonal array will be used for carrying out experiments for optimizing each of the output parameter.

Keywords: CO_2 moulding, Permeability, Dry compression strength, Dry shear strength, Optimization, Taguchi method, MINITAB

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 CO_2 passed through the mould. CO_2 reacts with sodium silicate and forms silica gel and in turn it hardens and imparts strength to the mould.

Permeability number should be above 200, DCS above 180 Psi and DSS above 38 Psi. 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 is applicable for the mould till pouring this experiment is carried out.

Cylindrical specimens of dimension 2”x2” will be made. Sand mixed with yellow dextrin and sodium silicate according to the specification in Taguchi method at three levels will be tested. Specimens will be made. Of which specimens will be tested soon after the specimen is made, then specimens after 1 hour from which specimen is made, and then specimen after 24 hours respectively. This is done to find out if any properties are coming out of required values as time passes on. Also to find out how the mould properties will change when molten metal is poured, the specimen is kept in a muffle furnace for 1 hour at 900^0C.

The permeability should be highest in each of above case. In case of DCS, it should be high when the mould is made, and it should be least after the molten metal is poured. DSS should also be in the same conditions as DCS.

L. Sasi Rekha et al [1] has presented a paper on green sand moulding system. This paper dealt with multi-objective optimization of green sand mould system using Part Swarm Optimization (PSO). It is important to note that improper levels of properties such as green compression strength, permeability, hardness and bulk density will lead to some casting defects [2] such as blow holes, pinhole porosity, poor surface finish, dimensional variation, scabs and rat tails etc. The properties are influenced by a large number of controllable parameters such as grain fineness number, % clay, % water and number of strokes. Therefore, to improve the mould properties by identifying the levels of input parameters is carried out in this journal. In this journal non-linear regression equations developed between the control factors, i.e. process parameters, and responses have been considered for optimizing using PSO. In this journal an attempt has been made to search for the optimal process parameter values for the multiple objectives, namely green compression strength, permeability, hardness and bulk density using PSO. Five different cases were considered by varying weighting factor of each objective. In this the percent deviations of the objective function values between the values obtained through PSO and experiments are found to be in the acceptable range.

A.Noorul Haq et al [3] demonstrates optimization of CO_2 casting process parameters by using Taguchi's design of experiments method. The process parameters considered were weight of CO_2 gas, mould hardness number, sand particle size, percentage of sodium silicate, sand mixing time, pouring time, pouring height, pouring temperature, and cooling time of poured metal. Casting defects [4] that may occur are swell, blow holes, pin hole, cold shut, shrinks, hot tears, honey combing etc. Here an L27 orthogonal array was taken with 3 level. Signal to noise ratio was calculated as three runs were conducted. ANOVA for casting defects and S/N ratio was also computed. Then the optimum CO_2 casting process parameters were calculated. Confirmation experiments were also carried out finally. It was found that percentage rejection rate of CO_2 casting process has decreased when the process parameters were set to an optimal level from that before setting the optimal parameters. 95% confidence level was taken.

A. kumaravadivel et al [5] prime focus was kept on minimizing the defects developed in the sand-casting process by Process Window Approach (PWA). Analysis of various critical process parameters and the interaction among them is carried out with the help of Taguchi method of experimental design. To optimize [7] the results obtained and to make the analysis more precise and cost effective, response surface methodology (RSM) is also incorporated. The optimized parameters obtained using the Taguchi method and RSM are then tested in an industrial case study. The process parameters [9] considered in this journal were moisture content, permeability, loss on ignition, compressive strength, volatile content, vent holes, pouring time, pouring temperature and mould pressure with three levels for each of the above parameters. An L27 orthogonal array [11, 12] was formed and experiments were carried out according to this. Three trial runs were taken and S/N ratios were calculated. The process parameters were optimized. M.Ravichandran et al. and others [6,8,10,13,15] adopted the well-established Taguchi technique for optimizing the several machining process which involves large number of complicated factors to be considered and they successfully optimized the parameters. So Taguchi method [14,16] can be utilized for optimizing the sand moulds which is also having some complex factors.

Experimental Setup

Mixing of sand will be done with the help of a sand muller. 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 CO_2 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 and DSS in kg/cm^2 which is converted to Psi by multiplying with 14.22. The values are tabulated and are optimized with the help of MINITAB software.

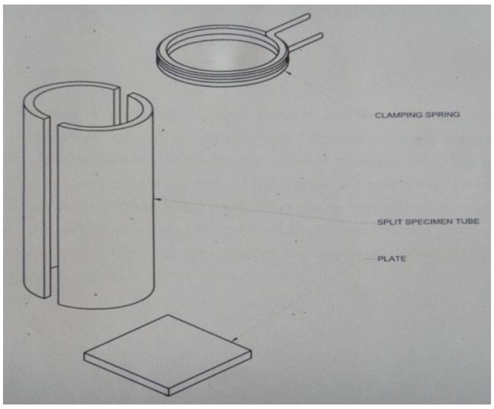


Fig 3.1: Sand muller

Fig 3.2: Split specimen tube schematic

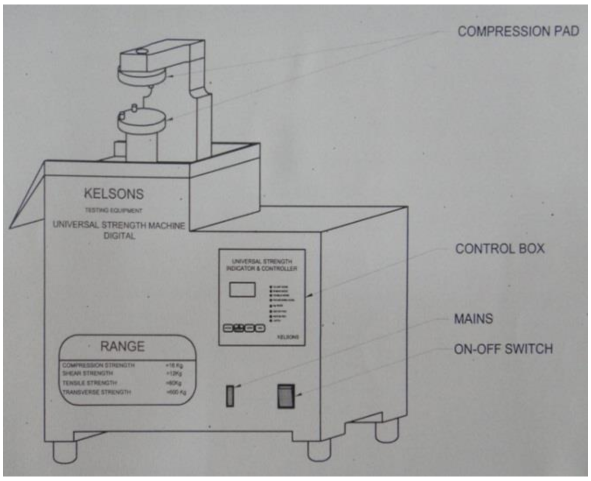


Fig 3.3: Sand rammer

Fig 3.4: Universal strength testing machine

The process parameters selected are shown in table 3.1

PARAMETER	LEVEL		
	1	**2**	**3**
AFS Number	39	41	44
Sodium Silicate (%)	3.5	4.5	5.5
Yellow Dextrine (%)	0	0.5	1.0

Table 3.1: Process parameters

An L9 orthogonal array was selected for carrying out Taguchi method as there were 3 parameters each at 3 levels as shown in above table. Selected L9 orthogonal array is shown below.

Expt. No	AFS number	Yellow Dextrine content (%)	Sodium silicate content (%)
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Table 3.2: L9 Orthogonal array

Experiments were carried out in three trials and the average value was taken to minimize errors.

Experimental Results

The obtained results are shown in the following tables.

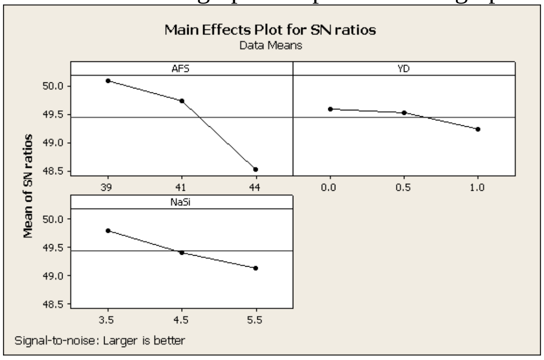
Sl No.	Spot Determination			After one hour		
	Permeability Number	DCS (Psi)	DSS (Psi)	Permeability Number	DCS (Psi)	DSS (Psi)
1	340	117.599	27.871	350	134.095	30.146
2	320	180.452	48.775	325	207.896	56.596
3	300	226.951	62.568	305	251.267	68.825
4	310	187.277	52.187	315	195.383	57.022
5	300	246.290	62.426	300	276.295	73.375
6	310	139.072	36.972	320	149.879	42.944
7	260	247.855	63.990	265	273.451	71.242
8	280	130.966	37.541	290	139.783	42.944
9	260	219.272	53.183	275	235.057	64.559

Table 3.1: spot determination and after one hour

Sl No.	After twenty-four hour			In Muffle Furnace for one hour		
	Permeability Number	DCS (Psi)	DSS (Psi)	Permeability Number	DCS (Psi)	DSS (Psi)
1	350	139.640	30.715	450	618.997	81.054
2	340	232.070	59.724	460	661.799	145.186
3	325	300.042	76.361	480	609.043	177.039
4	325	213.584	64.274	405	614.446	138.503
5	300	312.84	81.622	415	655.542	173.626
6	330	175.475	45.504	470	309.569	64.559
7	255	315.684	84.751	360	711.284	162.108
8	285	159.122	42.660	410	345.404	55.031
9	275	273.024	76.788	440	341.991	114.329

Table 3.2: After twenty-four hour and keeping muffle furnace at 900^0C for one hour

By using the MINITAB software, the results were analyzed and S/N ratio was found and graph was plotted. The graphs are as shown below.



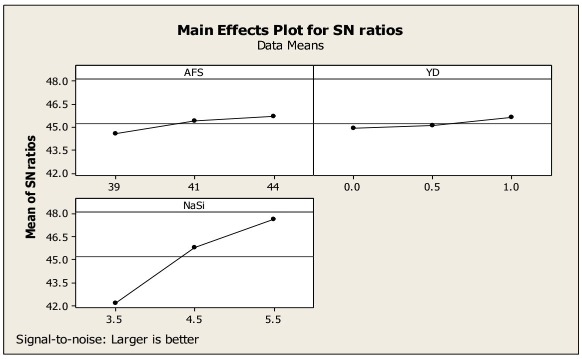


Fig 3.1: S/N ratio graph of permeability and DCS of spot determination

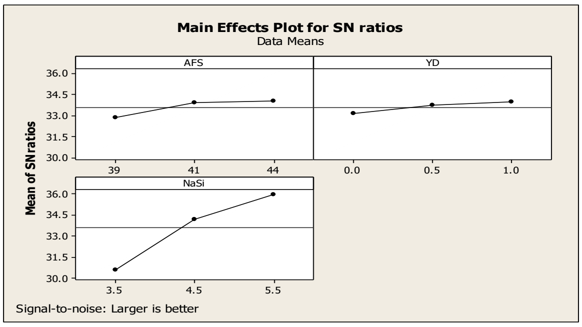
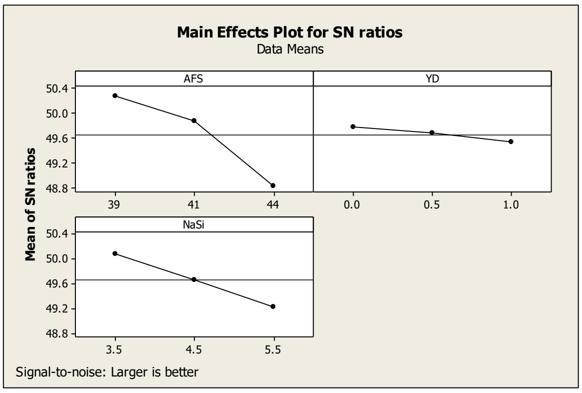


Fig 3.2: S/N ratio graph of DSS of spot determination



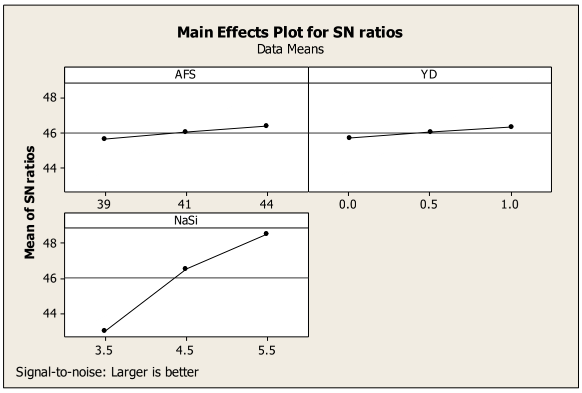


Fig 3.3: S/N ratio graph of permeability and DCS of After 1-hour experiment

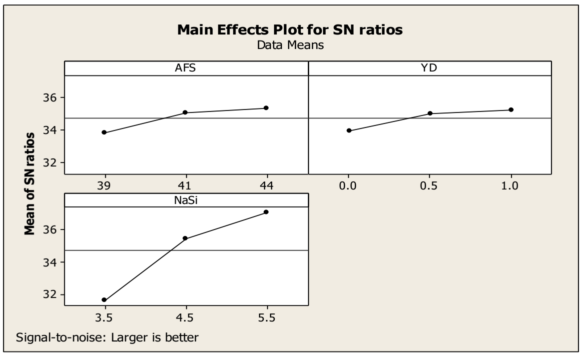


Fig 3.4: S/N ratio graph of DSS of After 1-hour experiment

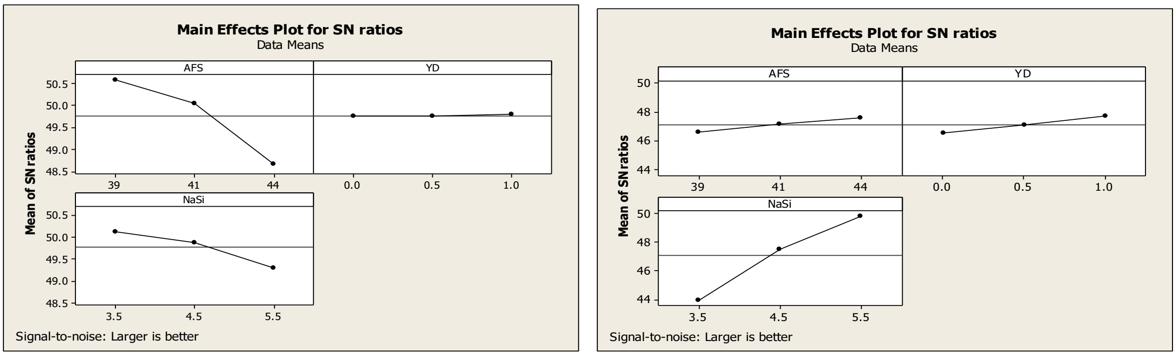


Fig 3.5: S/N ratio graph of permeability and DCS of After 24-hour experiment

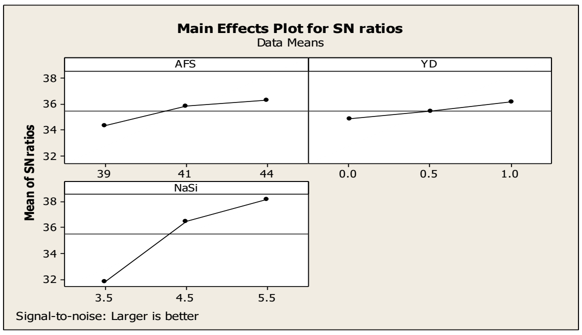


Fig 3.6: S/N ratio graph of DSS of After 24-hour experiment

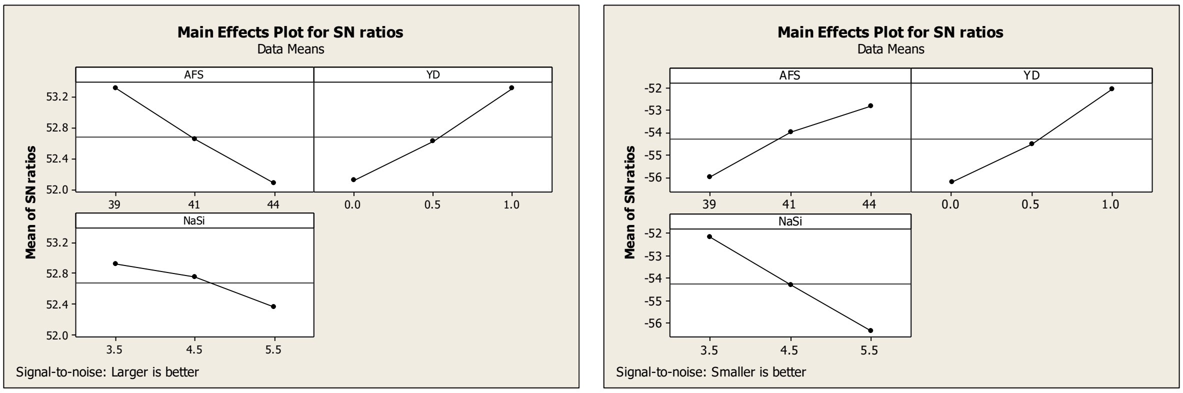


Fig 3.7: S/N ratio graph of permeability and DCS of in muffle at 900^0C for 1 hour

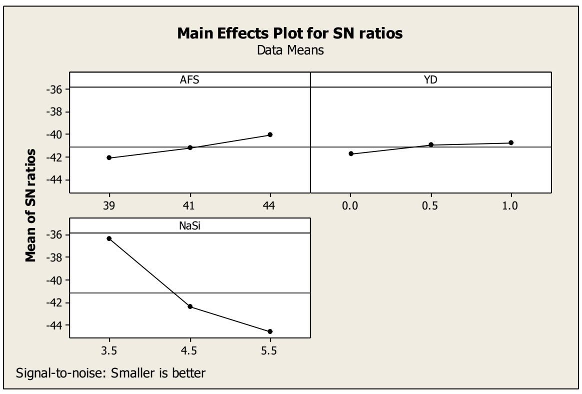


Fig 4.11: S/N ratio graph of DSS of in muffle at 900^0C for 1 hour

Conclusion

It is clear from the above graphs of S/N at 95% level of confidence level ratios the optimum parameters are 44 AFS number, 1.0% yellow dextrin and 4.5% sodium silicate for moulds in each case of spot, after 1 hour, and after 24 hours. But in case of heating in muffle at 900^0C for 1 hour the optimum results are 44 AFS, 1.0% yellow dextrine and 3.5% sodium silicate. But if a mould is made of 3.5 % sodium silicate, at initial phases in which molten metal is not poured 3.5% sodium silicate is not imparting required strength. So the optimum parameters are 44 AFS number, 1.0% yellow dextrine and 4.5% sodium silicate. The experiments are carried at 95% confidence level.

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