Parametric Optimization of Silicate Bonded CO_2 Mould made of Reclaimed Sand for Maximizing Compression Strength

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Abstract - Present work concentrates on optimization of process parameters of silicate bonded CO_2 mould made of reclaimed sand .Four process parameters i.e. percentage of sodium silicate, quantity of CO_2 gas, mixing time and coal dust addition are considered at two levels. Taguchi's L_8 orthogonal array is made use of .It is observed that all the considered factors are significant and obtained optimum confirmed through experimental validation.

Keywords – optimization, compression strength, orthogonal array

I. INTRODUCTION

Fast depletion of natural resources is a challenge to mankind .Casting is mother of manufacturing industries. Many types of moulding methods are available but, majority of castings are produced by sand moulding method. Once upon time sand is a cheap raw material and people used to throw away the knocked out sand. But now due to exhausting of resources, sand has become a costly commodity .In this situation one can't venture to throw away the sand out .Further dumping of knocked out sand at a faraway place creates environmental pollution problem .Hence foundry men are constrained to look for possibilities of reusing the knocked out sand. By virtue of dirt, dust, impurities and content of other additives,knocked out sand can't be used as it is .Hence this knocked out sand is to be subjected to some treatment, so that it can be effectively used for further moulding. This treatment of knocked out moulding sand for its reuse is known as sand reclamation.

Green sand moulding is widely used. Next best used sand moulding process is CO_2 sand moulding. In CO_2 molding, the sand is mixed with sodium silicate and this mix is poured around the pattern and is loosely rammed.CO_2 gas is sent into loosely rammed mass so that silica gel is formed between the sand grains. This silica gel bridge provides strength, hardness and permeability to mould. Silicate bonded CO_2 moulding process can be used for pouring castings of high density methods. Hardness of CO_2 mould is much higher than green sand mould. Hence CO_2 moulding process was first used for cores and latter used for producing castings. So problem with CO_2 mould is poor collapsibility. Hence reclamation is a challenge in case of CO_2 moulding process. When CO_2 moulding process was used for cores, reclamation is not considered important, but when CO_2 moulding process was used to produce castings, reclamation of CO_2 sands can't be ignored. Poor collapsibility problem of CO_2 process was addressed by Warren [1] and Nicholas[2].Though three types of reclamation methods are available, suitability of a specific method for a specific moulding process is to be discussed. Will [3] built up a prototype wet reclamation unit. Utility of wet reclamation system was reported by Jhonson [4].A gel fired fluid bed system is designed by Tilt[5] & Brown [6] for thermal reclamation .Regan et.al[7] evaluated effectiveness of thermal reclamation in organically bonded sand systems. Effect of temperature of sand on thermal reclamation is investigated by Hwang [8].Thermal reclamation is generally used for organically bonded sand systems. Problem with wet reclamation is requirement of extensive drying of sand after reclamation .Dry reclamation process is generally suited for hard and brittle binder. Shot blasting and crushing and grinding and dry attrition are different methods of dry reclamation. In CO_2 moulding process, owing to the brittle nature of Binder Bridge between sand a dry reclamation process with pneumatic attrition is used.

Properties of a mould depends upon values of process parameters namely percentage of sodium silicate, quantity of CO_2 gas, mixing time etc--- Hence a thorough comprehension is required for a foundry man, at what values of process parameters one can get a better property of the mould. So, current investigation concentrates on optimization of process parameters of CO_2 moulding process with reclaimed sand for better compression strength. Process parameter optimization studies on CO_2 moulding process with reclaimed sand is attempted by M.Venkata Ramana [9] for better Tensile strength. Previously many researchers applied Taguchi technique for optimization of process parameters [10, 11].Taguchi technique is a handy tool to systematically analyze the result and draw a meaningful conclusion with minimum amount of experimentation [12]. Present work utilises Taguchi method for optimization

II. OBJECTIVE

Objective of present investigation is to optimize process parameters of CO_2 moulding process with reclaimed sand for better compression strength.

III. STEPS INVOLVED

- Reclaiming the knocked out sand.
- Identifying process parameters and choosing of their levels and deciding suitable experimental plan
- Experimental determination of compression strength
- S/N analysis and Response graph
- ANOVA & F-Test
- Experimental validation through confirmation tests.

1 Reclaiming the knocked out sand.

Fresh silica sand with grain fineness number of 59.97 is used. Knocked out sand is subjected to dry reclamation process with impact and attrition .Principle of impact and attrition process is schematically represented in fig-1 and fig-2 respectively. In this reclamation process, knocked out sand is broken in to small pieces and powdered with the help of hardened steel pads. Then air is entered in to reclamation unit under pressure causing formation of whirl. This whirl causes sand particles strike against inside surface of container and also against each other. This, impact and attrition causes the residual binder coat on sand grains to be separated out. These separated residual binder coat particles will be eventually sucked out. Due to impact and attrition, the size and shape of sand grains may change which in turn affects mould characteristics and hence CO_2 moulding process with reclaimed sand are to be studied separately. Time of reclamation is very important. High reclamation times leads to excess attrition of sand grains and hence lead to decline in properties mould. Too low reclamation times result into improper removal of binder which in turn causes poor adhesion in subsequent bonding. M.VenkataRamana[13] experimentally determined optimum reclamation time as 15 minutes .Hence knocked out sand is reclaimed for 15 minutes.

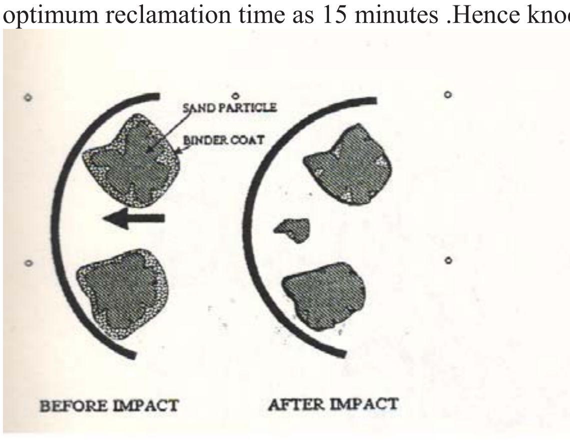

Fig:1 Schematic diagram of reclamation by impact

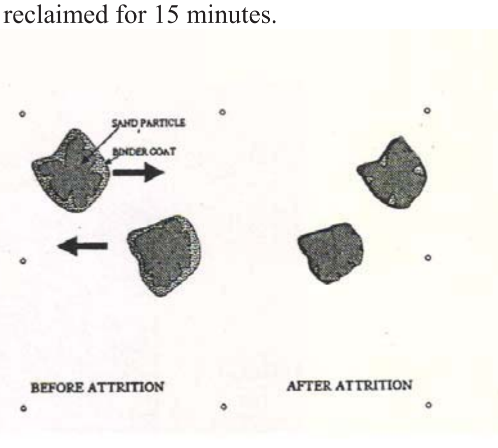

Fig:2 Schematic diagram of reclamation by impact

2. Identifying process parameters and choosing of their levels and deciding suitable experimental plan.

Percentage of sodium silicate, quantity of CO_2 gas and mixing time are the important factors considered to affect mould characteristics. Sodium silicate is the main bonding agent .Generally 3 to 6 % of sodium silicate is used in the process [14, 15] .In the current work, 4% and 6% are considered as two levels. CO_2 gas is the main curing agent.10 kg of CO_2 gas is required for 100 kg of sodium silicate to chemically balance the hardening reaction. On shop floor 40 kg of CO_2 gas is used for l00 kg of sodium silicate .Hence the two levels of CO_2 gas considered are 10 kg and 40 kg for 100 kg of sodium silicate. To exactly supply above quantities of CO_2 gas, a gassing arrangement is built up with CO_2 cylinder and a rotameter. Schematic of CO_2 gassing arrangement is shown in fig-3 .This gassing arrangement ensures constant flow rate of CO_2 gas to mould .So the two levels of CO_2 gas i.e 10 kg and 40 kg per 100 kg of sodium silicate are appropriately converted in to 13 seconds and 30 seconds gassing time. Hence the factor quantity of CO_2 gas is termed as gassing time. Too low mixing times leads to non homogeneous mix .On the other hand too high mixing times lead to heat generation and tell upon bonding characteristics of CO_2 mould. Generally used mixing times on shop floor is 5 to 10 minutes. Coal dust addition is made to improve collapsibility. Coal dust is considered as one factor and the two levels considered are 0% and 2%.Four factors at 2-levels and two, two level interactions are proposed to be studied .So a L8 Orthogonal array that can accommodate seven factors & interactions together is considered as experimental plan. Experimental plan is given in Table-1.

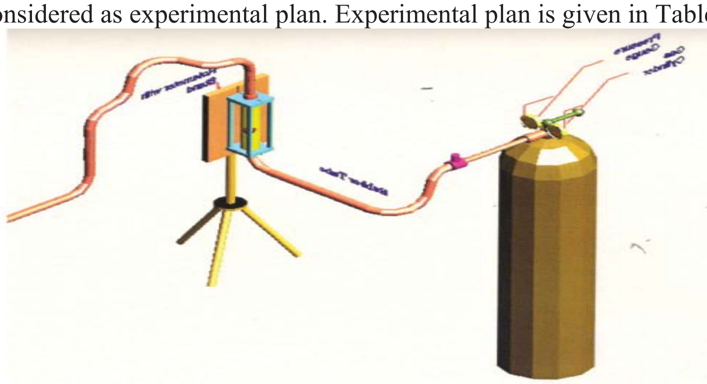

Fig:3 Schematic of Gassing arrangement

Table-1: Experimental Plan

Trial No	SS (1)	GT (2) (Seconds)	SSXGT (1X2)	MT (4) (Minutes)	SSXMT (1X4)	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.Experimental Determination of compression strength

As per the experimental plan mentioned in Table-1 2” X2” cylindrical AFS sand specimens are prepared. Compression strength of all the samples are determined using universal sand strength machine shown in Fig-4 .Tests are carried out as per standard AFS testing procedures 318-87-5,302-87-9-[15].Experimental observations are tabulated in Table-2.Each experiment is replicated thrice and average values and S/N ratio values are given in Table-2.

S/N ratio = -10 log(MSD) -----(1)

Where MSD= $[\, 1/y_1^2 + 1/y_2^2 + y_3^2 \,]/n$ for bigger the better type quality characteristic.

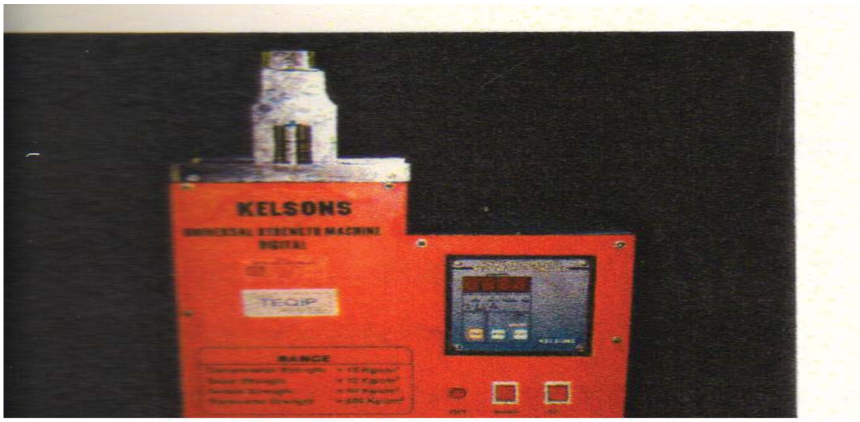

Fig-4 Universal sand strength Machine.

Table 2:Experimental values of compression strength

Expt. No	Compression Strength(Kg/cm^2)			Average	S/N Ratio
1	4.02	4.12	3.98	4.039	12.124
2	3.81	3.88	3.83	3.84	11.685
3	3.9	4.02	4.02	3.979	11.993
4	3.04	3.26	3.3	3.2	10.085
5	5.41	5.5	5.47	5.459	14.743
6	4.84	4.92	4.73	4.83	13.675
7	5.31	5.39	5.44	5.379	14.614
8	5.24	8.03	5.24	5.17	14.264
				4.487	12.898

4. S/N Analysis & Response graph

S/N analysis of experimental observation of Table-2 is made and the impact of each factor and interaction on compression strength is given in fig-5 in the form of response graph.. It can be observed that sodium silicate has got the highest affect on compression strength. During S/N analysis, always the quality characteristic is bigger the better type. For each factor the level values that has higher S/N value can be considered as optimum level. So the optimum condition is sodium silicate -6% ;Gassing time-13 seconds mixing time -5 minute and coal dust 2% .Though optimum condition is obtained from response graph,one can confirm it only after performing ANOVA and F-test.

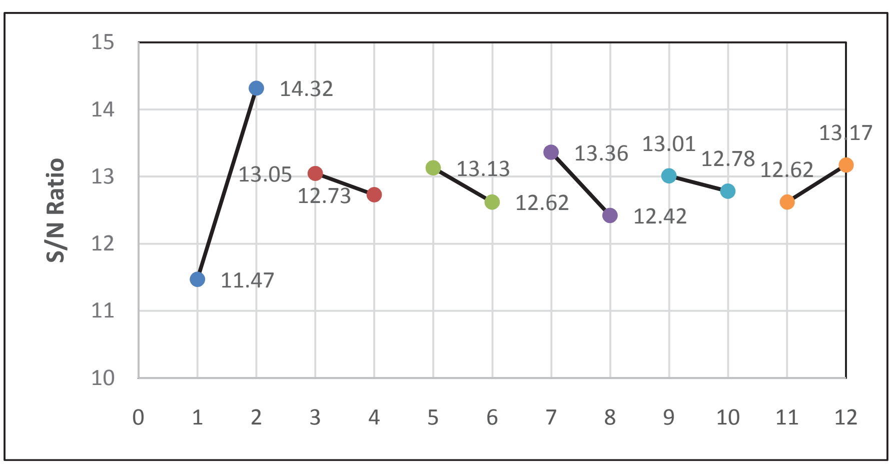

Fig-5- Response graph

5. ANOVA and F-Test

Analysis of variance (ANOVA) of experimental observations given in Table-2 are presented in Table-3.ANOVA Table gives us percentage contribution of each factor, F-ratio of each factor. Optimum condition obtained through response graph is fixed by eliminating insignificant factors. Discrimination between significant and insignificant factors can be made through ANOVA & F-test. By comparing F-ratio values of statistical table corresponding to degrees of freedom of factor and error degrees of freedom with F-ratio values of ANOVA table, it can be observed that sodium silicate, mixing time and coal dust are significant. As all factors are significant the optimum condition obtained from response graph holds good. i.e sodium silicate -6 % ,Mixing time -5 minutes ,Gassing time -13 seconds and coal dust -2%

Table-3 ANOVA Table for compression strength

Factor Name	**Dof**	**SS**	**Variance**	**F-ratio**	**Percentage of Contribution of factor**
SS	1	16.269	16.269	230.337	82.9
GT	1	0.201	0.201	2.855	1.02
SSXGT	1	0.6	0.6	8.495	3.05
MT	1	1.77	1.77	25.06	9.02
SSXMT	1	0.107	0.107	1.527	0.545
CD	1	0.598	0.598	8.469	3.048
Error	1	0.07	0.07		0.417
Total	7	19.618			100

Percentage contribution of each factor on compression strength is given in fig-6

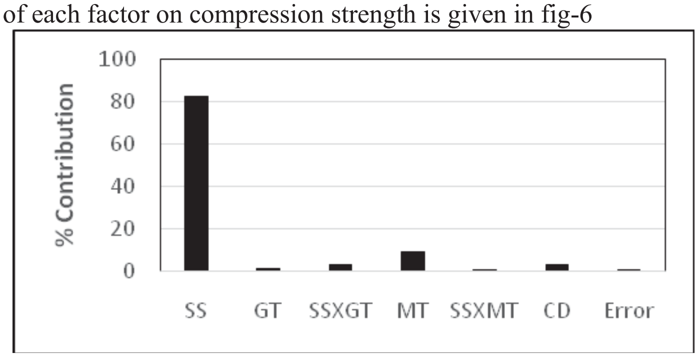

Fig-6 Contribution of each factor and interactions on compression strength

Expected compression strength *at optimum condition:*

Y optimum = $\bar{T} + [\bar{SS}_1 - \bar{T}] + [\bar{MT}_1 - \bar{T}]$

= 12.898+1.426+0.47=14.794 (S/N value)

=5.4916 kg/ cm^2(Actual value)

Range of expected compression strength at optimum condition

Confidence Interval (C.I)=+/- 0.2048

Range of Expected compression strength at optimum condition

=14.5892 to 14.998(S/N value)

=5.363 to 5.63kg/cm^2(Actual value)

Percentage of sodium silicate is observed to be the most significant factor affecting compression strength. As sodium silicate is the bonding agent, it is the obvious observation. But mixing time rather than gassing time" is observed to be the next best significant factor. Rounded grains of reclaimed sand can be attributed to this behavior.

6. Experimental validation through confirmation test

To validate the optimum condition obtained, confirmation experiments are conducted at optimum condition and average value of three experimental trials is observed to 5.47 ,which is well within the expected compression strength range at optimum condition.

IV. CONCLUSION

Process parameters of CO_2 moulding process are optimized using Taguchi method. Optimum condition for maximum compression strength is percentage of sodium silicate -6% ,gassing time – 13 seconds mixing time -5 minutes, coal dust- 2%.Optimum condition is experimentally validated.

REFERENCES

[1] D.Wawen, "The British Foundrymen", Vol.64, pp 449 (1969).
[2] KEL Nicholas, "The CO2 Silicate Process in Foundry", BCIRA (1972).
[3] P.C Will and R.H. Shurmer, "A Wet Method of Sand Reclamation ", 57th Annual symposium of AFS,pp 1-5 (May 6,1953).
[4] H.H. Hohnson,R.Y Mecleeny and G.A. Fischer, "Sand Reclamation in a Steel Foundry", 57 th Annual symposium of AFS ,pp 6-15.(May 6,1953).
[5] J.R Brown and C.Tilt , "Thermal Reclamation of Foundry Sands" British Foundry Plant and Equipment Manufacturing Association Conference (1981).
[6] J.R . Brown , "Reclamation of Chemically Bonded Sand", British Foundry Man, suppl.pp 169-176 (June 1979).
[7] R.W. Regan,R.C. Volget,R.L. Burt and R.R Bhamgara, "Use of Standard Sand Characterisation Tests to Indicate Effectiveness of Thermal Reclamation on Mixed Foundry Sand Wastes" AFS Transactions Vol.101 , pp 565-571 (1993).
[8] J.Y Hwang ,X.Liu and B.Kesling , "Sand Reclamation for a Steel Foundry", AFS transactions. Vol. 101 , pp 807-815 (1993).
[9] M.Venkata Ramana "Parametric Optimization of silicate bonded CO2 mould made of reclaimed sand for better Tensile Strength "International Journal of Latest trends in Engineering and Technology (IJLTET), Vol -5, issue -3, May 2015 , pp 465-470).
[10] M.Venkata Ramana "Parametric Optimization of silicate bonded CO2 mould made of reclaimed sand for better Tensile Strength "International Journal of Latest trends in Engineering and Technology (IJLTET), Vol -5, issue -3, May 2015 , pp 465-470).
[11] N.Logothetis and A.Haigh, "Characterizing and Optimizing Multiresponse Processes by Taguchi Method " ,Qual.Reliab.Eng .Int . 4 pp 159-169 (1988)
[12] A Bendell , J. Disney and W.A. Pridmore, "Taguchi methods: Application in World industry " ,IFS , IFS,UK (1989). IJ-1
[13] K.Srinagesh , "Chemistry of Sodium Silicate as a Sand Binder " ,Cast Metals Research Journal , pp 50-63 (March 1979)
[14] AFS Mould and Core Test Hand book " , pp 187-318 , The American Foundry men's society , inc .Des plains , II (1989)