EXPERIMENTAL INVESTIGATIONS FOR SPECIFICHEAT OF CO₂ SILICATE MOULDS

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ABSTRACT

The present study was carried out to determine the engineering properties of foundry sand to demonstrate the process parameters of CO₂-silicate moulds by using"Design of Experiments" in which all the variables will vary simultaneously. A temporary mould is prepared with the mixtures of sand, Sodium silicate to bind sand grains and some additives like bentonite and CO₂ gas were used to hydrolyze the mass of silicate sand. The process parameters considered are CO₂ gassing time, sand particle size, percentage of Sodium Silicate and time taken for heating process. The experimental investigations of thermal properties namely Specific Heat is studied to determine the effect of Sodium silicate, CO₂ gassing time. The adequacy of models is tested by the Analyses of Variance ANOVA which uses a computer program and accuracy by experimental data. Thus, the findings of this research suggest that the determination of individual, interactive and higher order effects of process parameters on the thermal properties of foundry sand are identified to a greater extent the rate of heat extraction from castings and also influences their quality of castings.

Key words: Molds, Foundry sand, Sodium Silicate, CO₂gas, Thermal Properties.

1.1 INTRODUCTION

In this process uses sand which has been mixed with Sodium silicate. CO_2 gas forms a weak acid to hydrolyze the Sodium Silicate and forms amorphous Silica to become a bond. This bonding action is from the Sodium Silicate itself. The use of CO_2 gives an almost instantaneous set. The mould is fully hardened before the pattern is drawn from the mould sections. Sodium Silicate is a versatile and widely employed solution. Sodium Silicate is likewise a liquid glass for good reason. When the water is dissolved it evaporates away for developing Sodium Silicate molds by using CO_2 at optimum gassing time [1]. The parameters are Sand particle size (number),Percentage of Sodium Silicate (%),CO_2 gassing time (seconds) and Time Taken for heating (minutes). The range of Sand particle size number was selected (1.18, 2, 2.36), Percentage of Sodium Silicate (2%, 4%, 6%), CO_2Gassing time (20 – 60 seconds) and Time Taken for heating (10-60 minutes) was selected. Molding materials are fire resistant granular materials with several types of organic binders and additives in a controlled ratio [2].

1.2 EXPERIMENTAL INVESTIGATIONS

Thermal properties determine to a large extent the rate of heat extraction, nucleation and growth within castings. Knowing thermal properties of the sand the desired directional solidification at different sections of the casting were created to improve its quality. Therefore, the following thermal properties of foundry sand will be studied. Specific Heat experiments were carried out at laboratory scale level to determine the basic mechanical properties of foundry sand. Sodium Silicate as a binder was used to prepare the moulds [3]. The Chemical reaction of Sodium Silicate with base sand is as follows, $Na_2CO_3 + SiO_2 \rightarrow Na_2SiO_3 + CO_2\uparrow$. Thermal properties were determined by heating the moulds by electrical instrumentation. The transfer of heat through the mould was noticed by Thermocouples. The aforementioned thermal

properties were calculated using empirical formulas.

The effect of Sodium Silicate, Grain size distribution, Number of ramming strokes and CO_2 gas passing time on heat transfer of the moulds was found. Materials and Testing of Molding Sands that were used in this research are Foundry Sand, bentonite, Sodium Silicate gel and water obtained from the foundry laboratory. The equipment that was used in this research for finding mechanical properties is Universal Sand Strength Testing Machine and for finding thermal properties is Heating Testing Equipment. Heating Coils is a special heating device that is shaped in a spiral design. The coil is typically made from a copper and heated through electrical current. When the coil is charged with electric power, it becomes red hot. This coil produces heat that is transferred into the surrounding area with a fan. A heating coil is also known as protectors. A thermometer has two

important elements, a temperature sensors in which some physical change occurs with temperature and some means of converting this physical change into a numerical value. When the metal tip of the thermometer comes into contact with the material it is testing, it conducts heat energy to the mercury.

The mercury turns into liquid and so it expands. It begins to rise up the tube where it stops is where we can take the temperature reading on the scale. Therefore. electrical instruments have a limited time response. Electrical Testing and Measurement devices can tell that a circuit or wire is energized as well as how much voltage or current an electrical circuit is carrying. By adjusting rheostat the voltage is set to be at 75V and current is set to be at 2A. Range of the instruments used: Rheostat (100W/5A), Voltmeter-75V/150V/230V (MI), Ammeter 5A/10A (MI).

Figure 1: Electrical Measuring Instruments

Consider two bodies at different temperatures, insulated from all other bodies, yet able to transfer heat to each other. The heat gained by the initially cooler body is equal to the heat lost by the initially hotter one. This equation is the basis of a class of experimental methods called "Calorimetry". Calorimetry allows us to measure the ratio of specific heat capacities of any pair of bodies. From the available heat transfer processes, conduction usually provides the most rapid heat transfer. Calorimeters are designed to be well – insulated, so no heat is gained from or lost to the surroundings. If no heating element is used to introduce heat in the system, the total heat transferred for the entire calorimeter system must equal zero. The basic strategy in Calorimetry is to use a temperature change and a heat capacity to determine a heat flow.

Specific heat is the amount of heat per unit mass required to raise the temperature by one degree Celsius. The relationship between heat and temperature change is usually expressed in the form shown below where C is the specific heat.

$$C = \frac{VIt}{jm(\theta + d\theta)}$$

Where is initial temperature and d θ is change in temperature from final to initial level. L is the length of testing coil in m and Joules constant = 4.186 and An SI unit of Specific heat is J/kg K.

1.3 Design Factorial Method:
Full factorial experiment is an experiment whose design consists of two or more factors, each with discrete possible values or "levels", and whose experimental units take on all possible

combinations of these levels across all such factors. A full factorial design may also be called a fully closed design. Such an experiment allows the investigator to study the effect of each factor on the response variable, as well as the effects of interactions between factors on the response variable. Further, a parameter need to be minimized with respect to a combination factors, whereas the one factor at a time procedure will not be considered. In this case 24 factorial design is used, four factors were studied designated A to D. The four factors selected were sand grain size, Sodium silicate percentage, Carbondioxide gassing time and Time taken for heating process.

Experimental work based on two levels and four factors has been carried out to establish the effect of factors considered on Sodium silicate moulds. ANOVA technique determines the controlling factor which significantly affects the quality characteristics.

Factors : 4   Base Designs : 4, 6

Runs : 6   Replicates : 5

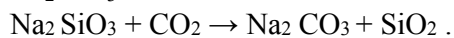The corresponding Design Matrix Parameters are shown in the Table 1 as below.

Table 1: Design Matrix Parameters Considered In the Sand Systems

Run	Grain size (A)	Percentage of Sodium Silicate (B)	Carbondioxide gassing time (C)	Time taken for heating (D)	Interactions					
					AB	AC	AD	BC	BD	CD
1	-1	-1	-1	-1	1	1	1	1	1	1
2	1	-1	-1	-1	-1	-1	-1	1	1	1
3	-1	1	-1	-1	-1	1	1	-1	-1	1
4	1	1	-1	-1	1	-1	-1	-1	-1	1
5	-1	-1	1	-1	1	-1	1	-1	1	-1
6	1	-1	1	-1	-1	1	-1	-1	1	-1

1.4 Experimental Procedure for CO2-Silicate Moulds:

Selection of sand grain size by using Sieve Shaker, Firstly a certain amount of foundry sand (say 1000g) of unknown grain size is taken and the size of the sand particle is measured by using sieve shaker machine. Sieve shaker which consists of stack of sieves for the purpose of separating a soil or other granular material sample into its component particles by size [4]. The stack of sieves is composed of sieves of different sizes. The sample is placed into the top sieve of the stack, and as the sieve shaker agitates the sample, the individual components shift through each of the sieve in turn with each one retaining particles of a successively smaller size and finally grain size of particular sand is obtained by using following observations. Sieving of sand is obtained grain size of particular sand of amount 30kg is sieved.

Weighing of required amount of sands for preparing moulds, and of particular grain size is weighted of amount 1000 grams by using weigh balance machine and 6% bentonite powder is mixed with this sand. Bentonite plays an important role in the preparation of moulds. Preparation of moulds by adding additives and binders, Take 1000g of sand, 6% of bentonite powder and mix it well in the container and pour 2% of $Na_2 SiO_3$ which appears as a Sodium gel plus 6% of water is added and stir it well until it becomes wet. Na2 SiO3 is used as a binder for preparing of moulds. The chemical reaction of $Na_2 SiO_3$ with base sand is as follows:
$Na_2 SiO_3 + CO_2 \rightarrow Na_2 CO_3 + SiO_2$.
By using Silica gel the moulds becomes very hard. Certainly by varying $Na_2 SiO_3$ (8%) and mix it well with the sand mixture and the required process is taken place [5] is as shown in figure 2. Drying the moulds by passing CO_2 gas,

after preparation of sand moulds CO_2 gas is allowed to pass through these moulds. By using the obtained 2% of Na_2SiO_3 five sand moulds are prepared and CO_2 gas is allowed on every mould by varying CO_2 - gassing time (i.e 20, 30,40,50,60 sec). It is left over for 1 day so that the sand moulds become very hard when compared previously is as shown in figure 3.

Drilling Process is done after the moulds become hard, the centre of the mould is marked. Holes are drilled on two sides of the centre hole for the purpose of placing thermometers. The procedure is to be done for 2% to 8% of Na_2SiO_3 by varying CO_2 gassing time (i.e. 20,30,40,50,60 sec) for every mould is as shown in figure 4.

Figure 2; Mould Cavity of Sheet   Figure 3: Passing of CO_2 gas   Figure 4: CO_2 – Silicate
Mould after drilling   process metal with co2 silicate moulds.

Next process is heating the moulds which influence the properties of sand moulds. Heating of moulds will be taken place by using the Electrical Measuring Appliances such as Voltmeter, Ammeter, Rheostat, Heating Coils

and Thermometers. The heated moulds are heated and their temperatures are noted down which are used for calculation of Specific Heat. The experimental setup is shown below:
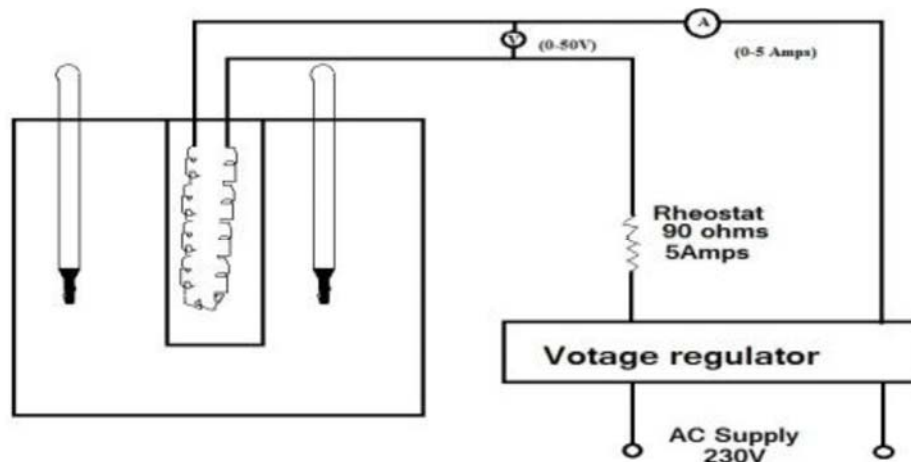

Figure 5: Schematic Diagrams for Experimental Measuring Instruments

Connections are to be made as per the circuit diagram. Heating coils is to be placed in middle of the hole which is on the mould and thermometers are to be placed on two sides of the holes. Initial readings of temperatures are noted. Then power is supplied and by varying Rheostat the Voltmeter is adjusted at 75V, ammeter is

adjusted at 2A throughout the process. By this the moulds will be heated and for every ten minutes the temperature readings is noted down. The process is taken place for 2% to 8% Na_2SiO_3 sand moulds and the required readings were noted.Then the thermal properties are calculated for every mould by using the formulae's.

1.5 RESULTS AND DISCUSSIONS
1.5.1 Effect on Thermal Properties of Varying Parameters:

In the present work, an attempt has been made to study the effect of Sodium Silicate percentage, CO_2 gassing time, heating temperatures and Grain size of sand on the thermal properties. Experimental setup for CO_2 silicate molding process is shown in figure 3.6. 1000g of sand was mixed with 6 weight percentage of bentonite and 4 weight percentage of tempering water added. Sodium silicate added at 2,4,6 weight percentages and the supply of CO_2 gassing times of 20 sec, 30 sec, 40 sec, 50 sec and 60 sec. The moulds are centrally drilled to accommodate the heating coil and two more blind holes are drilled to insert thermometers. The setup is as shown in the figure 4 about 5mm thick layer of glass wool is surrounded to the specimen to minimize the heat loss. During experimentation, voltage and current are kept constant to supply same input for all specimens. The rising temperatures are measured at regular intervals of time. The results are tabulated as shown with TABLE 2 to 3. Aforementioned thermal properties were calculated using empirical formulas by substituting their values. Results were ascertained and found thermal properties by means of graphical representation. The influence of variables considered in the work on the thermal properties will be critically discussed. Using ANOVA, the experimental values are checked for confirmation that is shown as below.

Table 2: Design Parameters Obtained For Specific Heat

S.No	Grain Size A	% of Na_2Sio_3 B	CO_2 gassing time C	Time Taken D	Specific heat C
1	1.18	2	20	10	0.0035
2	2.36	2	20	10	0.0044
3	1.18	6	20	10	0.0066
4	2.36	6	20	10	0.0065
5	1.18	2	60	10	0.0032
6	2.36	2	60	10	0.0038

TABLE 3 Estimated Effects and Coefficients

Term Constant	Estimated Effect	Co-Efficient	T- Value	P-Value
A	0.1027	0.0514	2.25	0.032
B	1.8699	0.9349	40.91	0.0
C	1.9393	0.9696	42.43	0.0
D	2.0434	1.0217	44.70	0.0
A×B	0.8475	0.4238	18.54	0.0
A×C	-0.4865	-0.2433	-10.64	0.0
A×D	0.2010	0.1005	4.40	0.0
B×C	1.1072	0.5536	24.22	0.0
B×D	1.1377	0.5688	24.89	0.0
C×D	2.7241	1.3620	59.60	0.0
A×B×C	-0.3935	-0.1967	-8.61	0.0
A×B×D	-0.1580	-0.0790	-3.46	0.002
A×C×D	-0.4797	-0.2398	-10.49	0.0
B×C×D	0.7881	0.3941	17.24	0.0

1.5.2 Main effect of thermal properties:

A main effect situation is when there exists a consistent trend among the different values of a factor. A main effect is a plot of the means at each level of a factor. A main effect occurs when the mean response changes across the levels of a factor and also uses main effect plot to compare the relative strength of the effects across the factors. In this graph, when the line is horizontal (parallel to x-axis) then there is no main effect and when the line is not horizontal then there is a main effect present.

In Main Effect Plot, Grain Size (A) and CO_2 gassing tiime (C) has no effect on the Specific Heat. Percentage of Sodium Silicate (B) has a small effect on Specific Heat whereas Time Taken (D) for heating shows a great influence on minimizing the effect on Specific Heat.
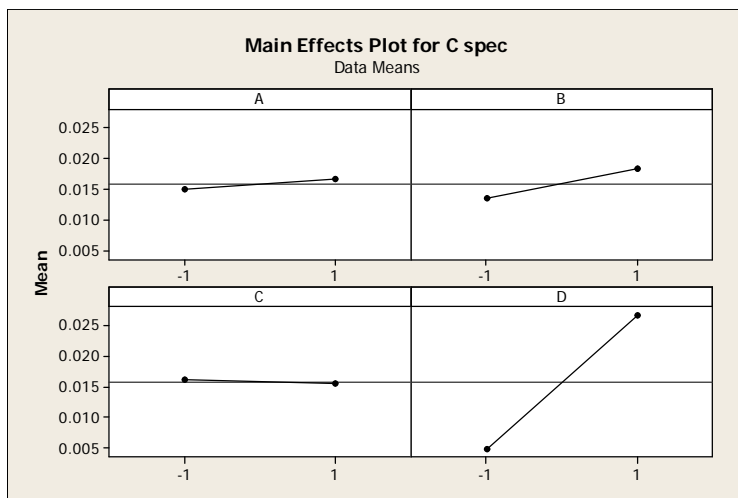

Figure 6: Main Effect for Specific Heat

CONCLUSIONS

Based on the Experimental study the following Conclusion is obtained.

1. Specific heat decreases monotonically with increase in sodium silicate content.

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