Evaluation of Sand Quality in Thermal Sand Reclamation System

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ABSTRACT

In casting industries, issue of spent molding sand disposal is the origin of molding sand reclamation. Among from all reclamation concepts the thermal reclamation method is better for no-bake sand system. This study focuses on the evaluation of sand quality by considering physical and chemical characteristics of molding sand, which is reclaimed by thermal reclamation method. Electric fuel and fluidization mechanism is used in thermal reclamation system. Effect of reclamation temperature, soaking period and sand quantity on % reclamability, grain size, ADV and on LOI is investigated. The average grain size, low ADV, low LOI and acceptable % reclamability of thermally reclaimed sand are studied.

Keywords: Thermal Reclamation; No-bake Sand Molding; ADV; LOI; Grain Size

1. Introduction

The casting is one of the prime manufacturing processes for producing components by melting and pouring, it mainly includes molding and casting. Molds and cores are the consumable parts of sand casting[1]. In casting process metal dies, sand molds or ceramic molds are used for casting. Over 70% of all metal castings are generally manufactured by means of sand casting. However majority sand molds and cores are made of silica sand, because it is the most easily available molding component. It has lower cost of tooling, broad scope of metals, and fewer limitations in part geometry, especially when compared to permanent mold processes[2,3]. After few cycles of operation, molding sand becomes unusable so that, it thrown away at dumping ground and it is environmentally undesirable. So that reuse of spent molding sand is required. The increasing cost of new sand as well as used sand disposal and the need to conserve available sources of high quality sand are the inspirations for sand reclamation concept.
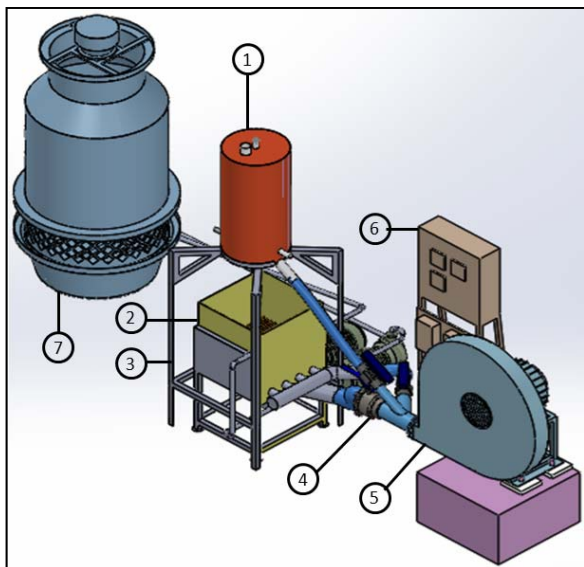
2. Need of Sand Reclamation

Sand reclamation is the physical, chemical or thermal treatment of foundry sands so that they can be safely re-used in place of new sand in molding and core making mixes. To reduce usage of new sand and to avoid environmental sand disposal issues, sand reclamation plays a prime role. Inflexible environmental dominance of sand disposal and massive utilization of new sand with the use of chemically bonded sands also increases the need of sand reclamation system. Three methods of sand reclamation are commonly used such as which includes Dry Reclamation, Wet Reclamation and Thermal Reclamation. In Thermal Sand Reclamation system, spent molding sand heated up to 800 °C temperature so as to burnout the binders due to application of heat. This system gives better sand reclamation.

3. Methodology

The Thermal Sand Reclamation system includes fluidized bed sand combustor, sand cooler, sand siever etc. Fluidized bed combustors (FBC) as well as sand cooler are the prime components. In FBC, sand heats up to resin decomposition temperature 500-8000 °C[4], which helps to burnout all organic and carbonaceous materials from the used sand. Fluidization mechanism plays a whittle role

for this sand heating, due to fluidization, uniform heating of each sand particle is achieved. The **Figure 1** represents the designed model of thermal sand reclamation system. The experimental thermal sand reclamation processing plant is manufactured and installed in laboratory as shown in **Figure 2**.The no-bake sand system has better strength than green sand casting. From the several types of No-bake sand systems, the selected type is "Furan acid cured". It is a two part system comprising of Furfuryl alcohol resin (0.9-2.0% weight of sand), and Sulphonic Acid Catalyst (0.2-1% by weight of sand) as molding ingredients[5]. **Figure 3** shows process flow of thermal reclamation.

1.FBC; 2.Sand Cooler; 3.Stand; 4.Air Ducts; 5.Blower for fluidization air; 6.Control Panel; 7.Cooling Tower.
Figure 1. Model of Thermal sand Reclamation system**.**

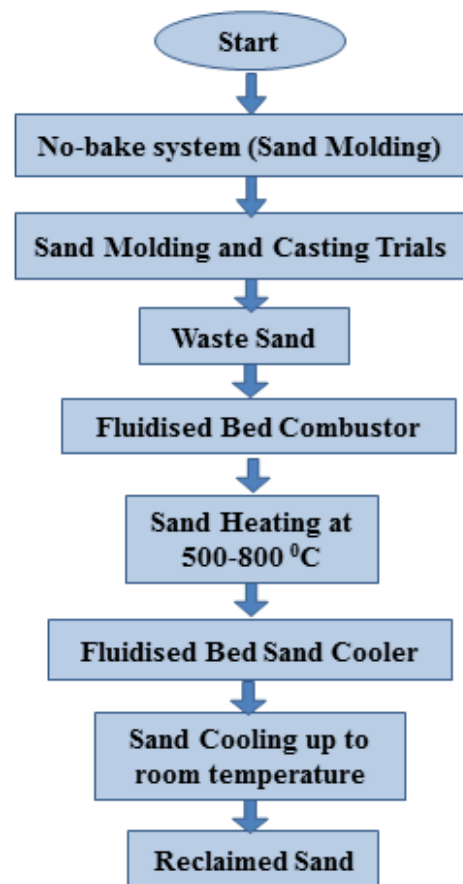**Figure 2.** Experimental setup of Thermal sand Reclamation system.

Figure 3. Process Flow of Thermal Reclamation**.**

4. Experimental work

In the thermal sand reclamation, there are several process parameters which affect the quality of reclaimed sand such as sand reclamation temperature, soaking time, sand quantity, and fluidization velocity of sand, heating time, cycle of reclamation[6-8]. To plan for experimentation, selection of processing parameters is the initial step.

4.1 Selection of Parameters

The reclamation temperatures, soaking time, sand quantity are the dominant process parameter which majorly effects on quality of reclaimed sand, so that, these parameters are selected as input parameters. Three levels of each parameter are selected as, 500, 650, 800 °C reclamation temperatures, 15, 20, 25 minutes as soaking time, and sand quantity 10, 15, 20 Kg as batch size. To evaluate reclaimed sand quality, several output parameters are selected such as, reclamability of sand, Grain fineness number (GFN), acid demand value (ADV), pH and Loss on ignition (LOI). The efficiency of system is measured in terms of % reclamability of

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sand which is ratio of weight of sand input to weight of sand reclaimed per batch. Grain fineness number gives average size of sand particles, which merely effects on permeability of molds. ADV and pH are the chemical characteristics of sand, which gives chemical behavior of sand. LOI gives the destruction efficiency of resin. The processing parameters studied in this research are shown in **Table 1**.

Table 1. The processing parameters with levels used for experimentation

Sr. No.	Parameters	Notation	Level I	Level II	Level III
1	Reclamation Temperature (°C)	A	500	650	800
2	Soaking time (min)	B	15	20	25
3	Sand quantity (Kg)	C	10	15	20

4.2 Orthogonal array

Experimental strategy with optimal number of iterations is set by orthogonal array. All the possible combinations of different levels of selected parameters (as mentioned before) are analyzed and L9 array is selected for actual experimentation. The selection of L9 array is depends on degree of freedom (DOF = 8), so, the selected array is greater than DOF[9]. **Table 2** represents the orthogonal array of three parameters and their levels.

Table 2. Orthogonal Array (L9) indicating levels of processing parameters

Expt. No.	Orthogonal array			Reclamation temperature (°C)	Soaking time (Min)	Sand quantity (Kg)
	A	B	C			
1	1	1	1	500	15	10
2	1	2	2	500	20	15
3	1	3	3	500	25	20
4	2	1	2	650	15	15
5	2	2	3	650	20	20
6	2	3	1	650	25	10
7	3	1	3	800	15	20
8	3	2	1	800	20	10
9	3	3	2	800	25	15

According to experimental strategy, experiments are performed. Initially spent molding sand is loaded to FBC, then heating starts. Simultaneously air is introduced in FBC through nozzles by using 5HP blower for fluidization, to achieve uniform heating. In FBC sand is heated up to elevated temperature. The spent molding sand loading to FBC and unloading of hot sand from FBC is shown in **Figure 4**. The sand cooler is placed exactly at bottom of FBC, so unloaded hot sand from FBC is directly loaded to sand cooler. Here hot sand is cooled up to room temperature by fluidization and water cooling arrangement, the cooled sand is passed through different sieves to sort it according to required mesh sizes. This reclaimed sand is unloaded from sand cooler and used for evaluation. The treated reclamation sand and untreated spent no bake sand is shown in **Figure 5**. The reclaimed sand is evaluated for selected output parameters; all the output values are shown in **Table 3**. The all output values are utilized to show their correlations with input parameters through graphs and tables. Minitab-16 software is used to analyze the output values.

Table 3. Output parameters and their values

Expt. No.	Reclamation temp. (°C)	Soaking time (min)	Sand quantity (Kg)	% Reclamability	GFN	ADV	% LOI
1	500	15	10	85	45	7.1	1.6
2	500	20	15	87	51	6.4	1.8
3	500	25	20	95	45	6.7	1.7
4	650	15	15	97	50	6.6	1.5
5	650	20	20	75	48	7.2	1.8
6	650	25	10	90	51	6.7	1.9
7	800	15	20	65	56	7.1	2.0
8	800	20	10	40	51	6.4	2.2
9	800	25	15	75	52	6.5	1.7

Figure 4. Fluidized bed combustor showing **A**) Loading and **B**) unloading of hot sand.
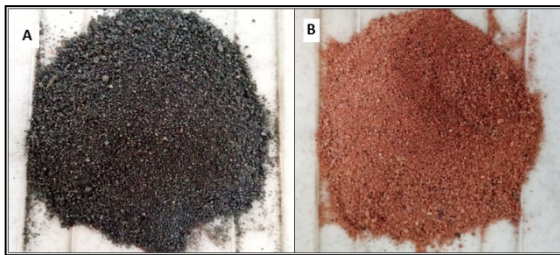

Figure 5. Quality of Sand **A**) Before Reclamation and **B**) After Reclamation.

5. Results and Discussion

5.1 Measurement of Reclamability

Quantification of reclamability is nothing but the efficiency of the thermal sand reclamation system with respect to various process parameters. The contribution of selected parameters such as reclamation temperature within 500-650 °C, soaking period of 25 minute for Sand batch of 15 Kg, gives better reclamability as shown in **Figure 6**. The graph of % reclamability w.r.t experiments shows that in **Figure 7**, the experiment no. 4 gives higher value of reclamability along with 650 °C.
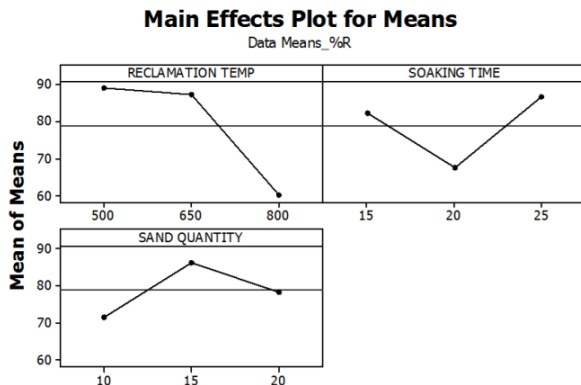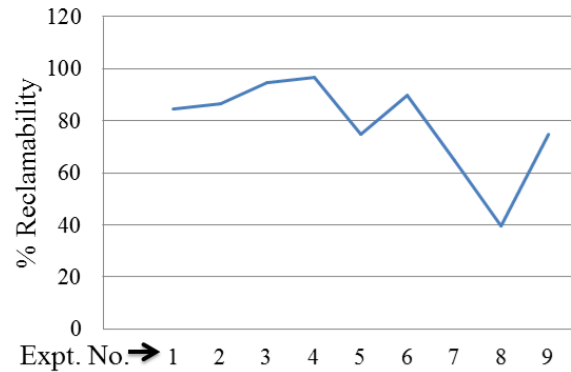

Figure 6. Mean effect plot for % reclamability.

Figure 7. Variation in % reclamability.

5.2 Measurement of GFN

The grain size analysis of reclaimed sand is necessary[11] because, permeability, compressive strength of mold and surface finish of casted part is also depends on it. 40 to 50 GFN (340 μm to 280 μm) is suitable for sand molding[10]. The GFN of all samples are analyzed and mean effect graph is plotted and presented in **Figure 8**. When 15 kg of sand is heated up to 500 °C temperature with 25 min soaking, then it gives best average grain size of sand particles. As per the variation in selected input parameters different GFN values are obtained and it can be plotted as per **Figure 9**. It shows that the all values are within the acceptable range except the experiment seven.
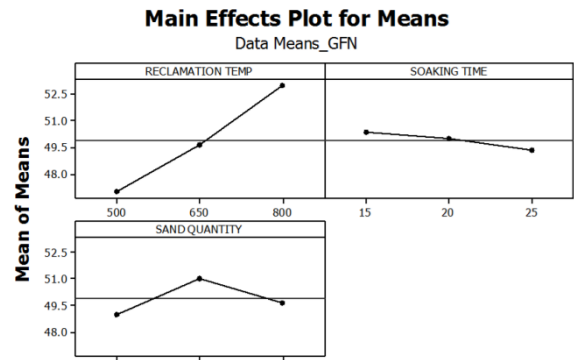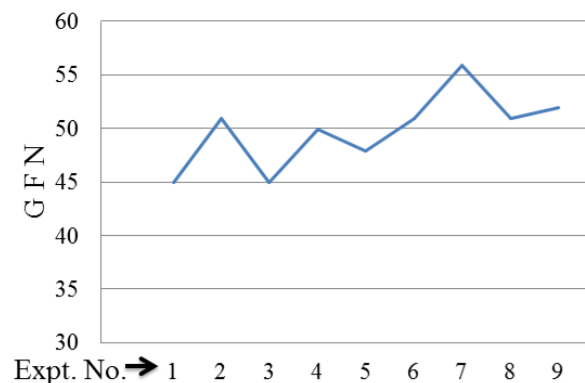

Figure 8. Mean effect plot for GFN.

Figure 9. Variation in GFN.

5.3 Measurement of ADV

Acid demand value estimates the chemical behavior of reclaimed sand with acid[11]. Minimum value of ADV means minimum reactivity with acid and it is suitable for molding sand. Greater than 6-10 mL acid demand is not acceptable ADV for acid catalyzed binder system[12]. The mean effect plot of acid demand value is presented in **Figure 10**. The method adopted[13] for calculating ADV is as follows, in 50 gram sand sample 50 mL distilled water and 50 mL 0.1N HCL are added. After 10 min stirring and decanting, filtration of the mixture is done. Then titration of filtrate is carried out with 0.1N NaOH to phenolphthalein end point.

ADV = (Quantity of 0.1 N HCl-Quantity of 0.1N NaOH)   (1)

The calculated ADV is plotted against experiments, presented in **Figure 11**. We found that all values of ADV are within 6 and 7.2, which is more desirable.
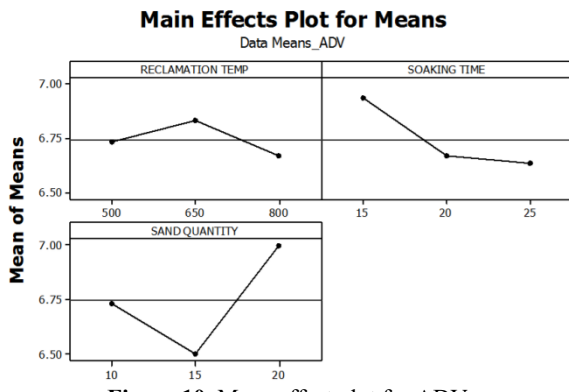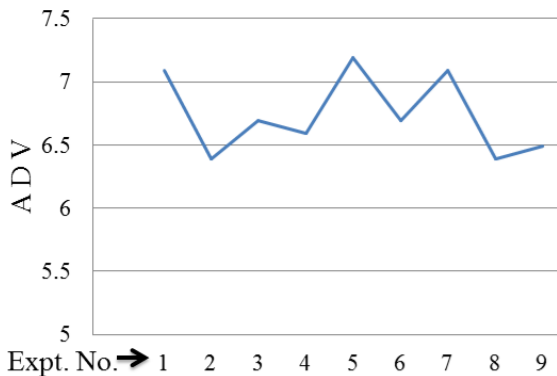

Figure 10. Mean effect plot for ADV.

Figure 11. Variation in ADV.

5.4 Measurement of LOI

LOI estimates the amount of degradable material or impurities or moisture to be loss at high temperature[14]. The mean plot as shown in **Figure 12**, it is expressed that, estimated LOI is less when reclamation for 15 Kg of sand is done at 500-650 ℃ temperature w.r.t 15 min soaking time. For LOI, reclaimed sand sample is heated up to 900 ℃ (time two hours). Difference of weight of reclaimed sand before and after heating is divided by initial weight of sand; it gives LOI[15]. The **Figure 13** represents the variation of LOI w.r.t. experiments. All values of LOI's are below 2%, except experiment eight.

20 Kg capacity of system was used for sand reclamation, and for better results, electric fuel was designated for heating purpose, but during some experiments due to continuous heating some sand was clogging, and the care was taken for that.
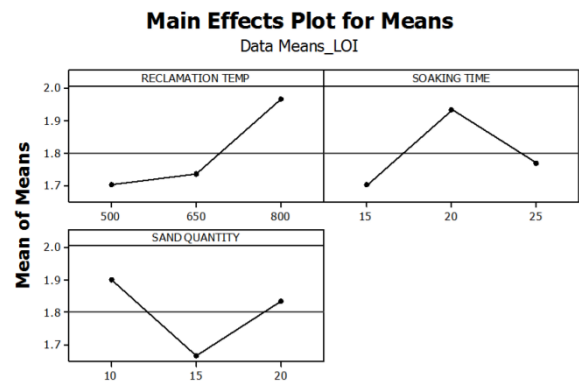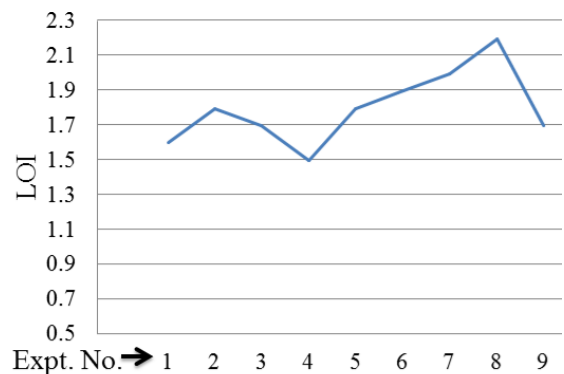

Figure 12. Mean effect plot for LOI.

Figure 13. Variation in LOI.

6. Conclusions

The results described in this study assist to a conclusion that the process or system in which the reclamation of spent molding sand is achieved may help to evaluate the quality of reclaimed sand, which will significant for its effectiveness. The main intension of this work is to find out quality of sand after reclamation, so the following conclusions are made,

(1) During current investigation, the effective

reclamation of no-bake (organic) binder system is achieved at 500-650 °C, so heating at 800 °C or above is not required[6,8].

(2) The GFN of reclaimed sand with current system is found between 45 and 55 (300 μm to 240 μm); it is suitable[10].

(3) The diagnosis for ADV represents, the ADV of reclaimed sand is about 6-7, which helps to achieve better casting quality[12].

(4) LOI of reclaimed sand was found near about 2% indicating less degradable material which ensures minimal gas related defects in castings.

Acknowledgements

Conflict of interest

The authors declared no conflict of interest.

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