Optimization of Time and Temperature for Thermal Reclamation of Furan Resin Based Sand

Monish A, B S V S R Krishna

ABSTRACT--- The moulding sand is an important material in foundries to produce the castings and there is no suitable substitute for this sand invented so far. The availability of good quality high silica sand suitable for foundry industry is becoming scarce due to high demand and also strict restriction in mining of sand due to ecological reasons. The reclamation of used sand is becoming mandatory in order to avoid the scarcity and also disposal of used sand has become a serious issue due to environment reasons. Hence an attempt has been conducted in detail on furan resin bonded used sand collected from various foundries in and around Coimbatore area. The furan based used sand properties like loss on ignition (LOI), total gas evolution, sulphur content & pH were measured. Experiments were conducted in muffle furnace on collected samples at different time and temperature to identify the suitable and feasible properties of thermally reclaimed sand with fresh/new sand.

Index Terms— Thermal reclamation, loss on ignition (LOI), total gas evolution, sulphur content, foundry, high silica sand.

I. INTRODUCTION

The Indian Metal casting (Foundry Industry) is well established. World census conducted by modern Castings USA on casting production, India stood at 2nd largest in casting production with 7.44 Million MT of castings. One to two metric tons of sand is used for one ton of the castings produced by Indian foundry [1]. The metal castings produced by Indian foundry is used for different applications in various metal industries. Modern foundry is facing a huge problem of finding new sand source due to mining restrictions; hence the only alternative left over is to reuse the sand i.e sand reclamation. But many foundries do not follow this process due to very high cost involved in this process [2]. Traditionally the production of 1 metric ton of casting from ferrous alloys generates 1 metric ton of waste [3], this also contains certain amounts of harmful, dangerous compounds and should undergo a reclamation – at least for the main component, which means a silica sand grains. Reclamation is a treatment process to recover atleast one component with similar properties of the new component for reuse in casting moulds and core production. Waste sand which comes from foundry industry consists of various components such as binding agents and other chemicals. These chemicals and binding components should be removed from this sand and recover the sand which has high silica and bentonite [4].

Foundry industry uses mainly three reclamation methods for recovery of sand. The technology and methods are well known for these three methods namely i.e dry method, wet method and thermal method. Dry reclamation may be divided into pneumatic and mechanical. In dry reclamation processes lumps are crushed to grain size followed by mechanical abrasion then removes part of the binder from the sand grains. The fines are separated using classification and the sand is ready for reuse. The wet process uses the water for separation of binding materials. The waste sand lumps are crushed to grain size and metal objects are separated with help of magnetic separation. Soluble materials (such as Na_2O) from the waste sand is washed with water. The sand is dried for reuse. Traditional reclamation technologies are not always enough intensive to liberate silica basis from the envelope of used binding material, thus new innovative methods are investigated to improve the reclamation effectiveness. Thermal reclamation method is mainly aimed for the reclamation of spent sands containing organic binders [5]. This process also used for binder deactivation. The advantages of thermal reclamation process are accurate removal of binding agent, possibility of using complete sand for the production of fresh moulding and core sands as the sand retains the size as no mechanical abrasion is present in the process. This process produces very less chemical harmfulness dust to the atmosphere [6]. Thermal reclamation is carried in fluidized beds. The binding material is completely combusted with air/oxygen from waste sand. The binding material, sand physical and chemical properties will decide the conditions and operation of fluidized bed or any other type to thermal reclamation. The reclaimed sand from thermal reclamation maintains the proper shape and clean for further usage similar to new sand [1]. Electrically heated fluid bed is proved to be satisfactorily produced the proper reusable sand which is novel and innovative [7]. Gas fired fluidized bed system was used for thermal reclamation of Zirconia sand with furan polymer binder. 99.8% reclaimed sand is matched with new sand [8]. The reclaimed sand must check (visual or preliminary tests) to maintain the fresh sand. Most of the times the colour of the waste sand will give an indication of LOI, pH, sulphur content and strength of mould (either

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Monish A, Department of Chemical Engineering, MIT, MAHE, Manipal, Karnataka, India. (E-mail: monishcoorg@gmail.com)

B S V S R Krishna, Professor, Department of Chemical Engineering, MIT, MAHE, Manipal, Karnataka, India. (E-mail: Krishna.bandaru@manipal.edu)

compression strength or tensile strength). If iron oxide additives have been made to the sand, it reduces the refractoriness of the reclaimed sand [5]. During casting stage, high fumes may be liberated if the reclaimed sand contains high LOI. This high fumes generation may be the presence of sulphonic acid catalysed furan resins in sands. The strength characteristics of thermally reclaimed sand is gradually high than that of new sand, Hence the authors focused on time of heating and this may reduce the heat required, so that the pollution can be reduced [9]. The present research focused on optimizing the time of heating and temperature for thermal reclamation of sand.

II. MATERIALS AND METHODS

A. Materials

Sand (used) samples collected from various industries were taken in specified quantities and sun dried. The sand was sealed in air tight container to maintain the same quality of raw material for experiments. Muffle furnace was used as a heat source for all the heating experiments. Small quantity of used sand taken in silica crucibles and temperature maintained at 800^{0}C for known time and visibly noted the change of colour of the sample. Repeated the experiment at 700 ^{0}C, 625 ^{0}C, 600 ^{0}C, 550 ^{0}C and 500 ^{0}C with fixed time intervals at 2, 5, 10, 15 min.

B. pH measurement

Used/treated sand (50 g) was mixed with 100 ml of distilled water and stirred for at least 5 minutes. Supernatant liquid was collected separately at short time intervals and used for pH measurement. The test shall be carried out at 27±2 ^{0}C.

C. Determination of loss on ignition (IS 1917-1-1991)

Platinum crucible is used for this test. The platinum crucible with sample is kept in muffle furnace and slowly raised the temperature to 1000^{0}C, hold the sample for 30 minutes at this temperature. The sample is cooled and weighed. Repeat the same procedure till constant loss of weight is obtained. The sample weight to be used in this experiment was exactly 1 gm.

D.Percentage of sulphur by CS230 carbon sulphur determination

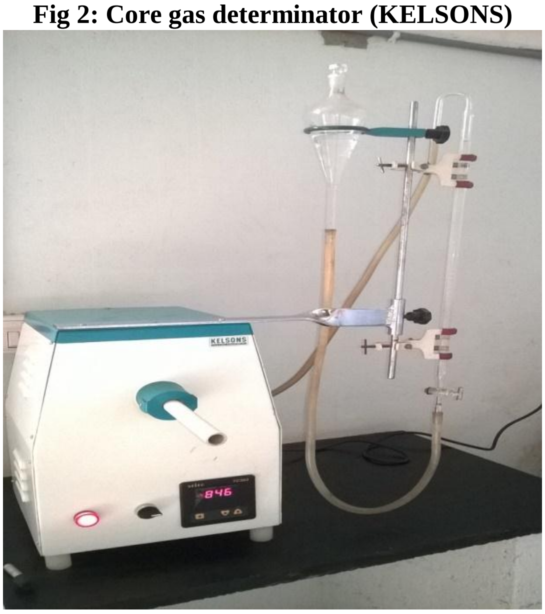
The CS230 Carbon/Sulphur determination apparatus measures the carbon and sulphur content present in metals, ores, ceramics, and other inorganic materials. The apparatus shown in Fig.1. Sample required for this experiment is exactly 1 gm. The sample is combusted in a stream of oxygen. The carbon present in the sample will be converted as carbon dioxide and some amount is converted as carbon monoxide. Sulphur dioxide is formed from sulphur. These gases along with excess oxygen will passed through dust filter and drying agent. After filtration these gases will enter into an infrared cell (IR) where sulphur dioxide is detected. The carbon monoxide and sulphur dioxide are converted to carbon dioxide and sulphur trioxide with the help of catalyst at elevated temperatures. The sulphur trioxide is removed in a filter and carbon dioxide is measured in a separate IR cell. The concentrations of carbon dioxide and sulphur trioxide concentrations are identified using IR cells.

Fig 1: CS230 carbon/sulphur determinator

E. Determination of gas generated in core during baking-(IS 1918-1966)

The foundry men are also concerned about the gas generated within a core during baking, pouring and solidification of the metal. Core gas generation is measured by core gas generation apparatus and shown in Fig. 2. Tared combustion boat or suitable crucible is preheated and a desiccator is used for cooling. The crucible is kept in desiccator for further use. Exactly measured 2 or 3 grams of sample kept in crucible and placed in the combustion tube present in the apparatus. The sample was heated to 1000 ^{0}C in carbon dioxide or nitrogen atmosphere. The evolved gas is measured in exit. The volume of the gas collected in the burette and readings measured for every 30 s. The final volume of the gas also measured and noted. This experiment takes approximately 10 to 12 minutes.

Fig 2: Core gas determinator (KELSONS)



For the purpose of suitability the samples are given alphabetical names as shown table 1 and 'Z' is used sample from foundary (control sample).

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Table1: Treated sand sample names

Temp. (^{0}C)	Time (minutes)			
	2	5	10	15
500	A	B	C	D
550	E	F	G	H
600	I	J	K	
625	L	M	N	
650	O			
800	P			

III. RESULTS AND DISCUSSION

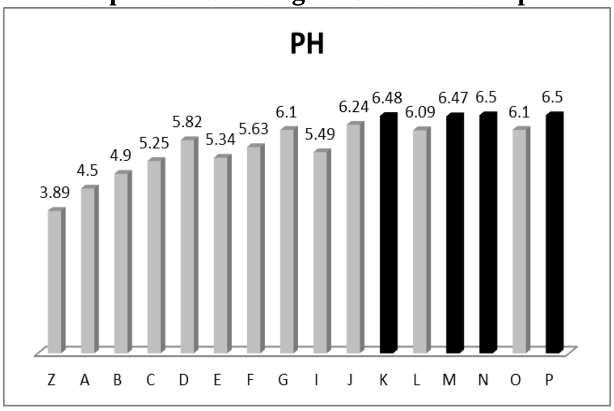
A. Feasible Studies

Preliminary feasible studies conducted using the table 1 conditions. Visually verified the color of thermally reclaimed sand. Visual verification of color of the sample M, N, K is very close to new sand. Though O and P experimental conditions are high temperature but the time is less, the O and P color is same as original sample "Z". The experimental conditions of M, N, K are 625 ^{0}C for 5 minutes, 625 ^{0}C for 10 minutes, 600 ^{0}C for 10 minutes. From the above test (visual) samples M, N, K are found to be suitable.

B. pH comparison

Treated sample (50 g) is mixed with 100 ml of distilled water and stirred for at least 5 minutes. Supernatant liquid is collected separately at short time intervals and used for pH measurement. The test shall be carried out at 27±2 ^{0}C. Fig 3 shows the variation of pH with temperature and time.

Fig 3: Variation of pH with temperature and time and its comparison with original untreated sample



The pH of original sample "Z" is 3.89 while the sample K, M,N and P are very close to 7 or neutral in pH. The samples K,M,N and P are more close to the new sand as the pH of these sands are close to neutral.

C. Loss on ignition

The sample is ignited at 1000 ^{0}C in a muffle furnace and the loss in mass is measured and compared in table 4 with original sample "Z". Fig 4 shows the comparative graph of thermally reclaimed sand samples with original sample "Z".

Fig 4: Comparison of loss on ignition of samples with original

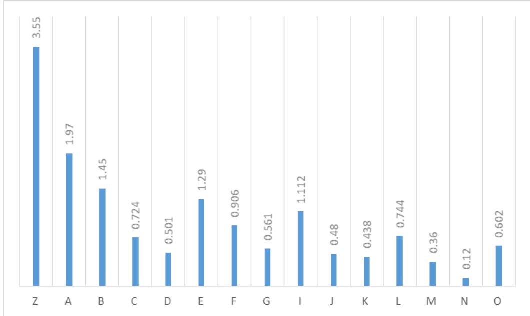


Table 4: Comparison of percentage loss of ignition

Sample name	Percentage loss on ignition (%)
Z	3.55
A	1.97
B	1.45
C	0.724
D	0.501
E	1.29
F	0.906
G	0.561
I	1.112
J	0.48
K	0.438
L	0.744
M	0.360
N	0.120
O	0.602

The original sample has highest loss of ignition as the sample "Z" is untreated used furan sand while all other samples loss of ignition is more than "Z". The samples with less than 0.5% may be considered as suitable to replace the fresh sand in foundary [10]. The optimized conditions are D, J, K, M, N sample conditions.

D. Sulphur content

The CS230 Carbon/Sulphur determination apparatus is used to measure the sulphur content in the sample. Table 5 has presented the percentage of sulphur content in the samples along with original sample "Z", the same is represented in Fig 5.

Fig 5: Comparison of sulphur content in samples with original

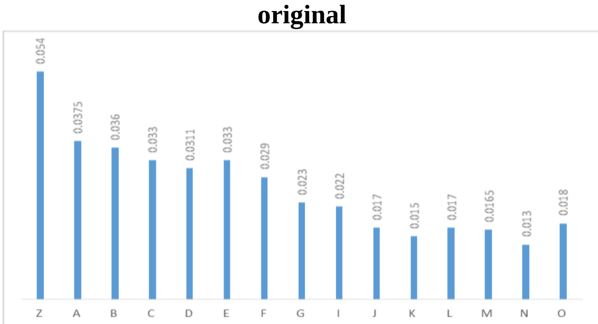


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Table 5 : Sulphur content present in the samples

Sample name	Percentage sulphur content
Z	0.054
A	0.0375
B	0.036
C	0.033
D	0.0311
E	0.033
F	0.029
G	0.023
I	0.022
J	0.017
K	0.015
L	0.017
M	0.0165
N	0.013
O	0.018

The Sulphur content present in original (Z) is very high as the sample is freshly used furan resin based sand sample. Treated samples sulphur content considerably reduced. The sulphur content should be less in treated samples and may be in the range of 0.01 to 0.02% range [11]. The samples within this range are identified as J, K, L, M, M and O. This is in agreement with [11].

E. Gas generated in core during baking

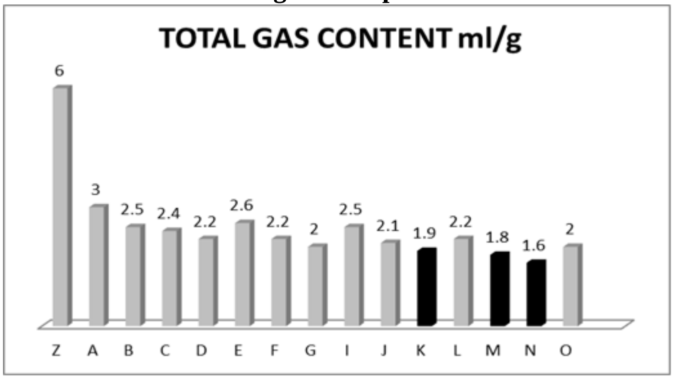
Core gas generator is used to measure the volume of gas evolved per gram of sample in millilitres. Figure 6 shows the variation of gas evolved during baking and table 6 shown the comparison with original sample "Z"

The core gas content present in original (Z) is very high (6 ml/gm) as the sample is freshly used furan resin based sand sample. Treated samples core gas content considerably reduced. The core gas content should be less in treated samples and may be in the range of 1 ml/gm to 2% range [12]. The samples within this range are identified as K, M, M. The results are in agreement with [12].

Table 6: Gas evolved during baking

Sample name	Gas content ml/g
Z	6
A	3
B	2.5
C	2.4
D	2.2
E	2.6
F	2.2
G	2.0
I	2.5
J	2.1
K	1.9
L	2.2
M	1.8
N	1.6
O	2

Fig 6 comparison of gas evolved during baking with original sample



F. Compression strength

The compression strength of thermally reclaimed sand choosen only one from the present work "sample M" and mechanically reclaimed sand collected from local foundary industry along with fresh sand are used for comparison. The results are presented in table 7 and also figure 7.

Table 7 compression strength of different sands

Sand type	2nd hour strength	4th hour strength	24th hour strength
Mechanically reclaimed sand	19	26	30
Thermally reclaimed sand at 625^{0}c	4	15	24
New sand	3	10	19

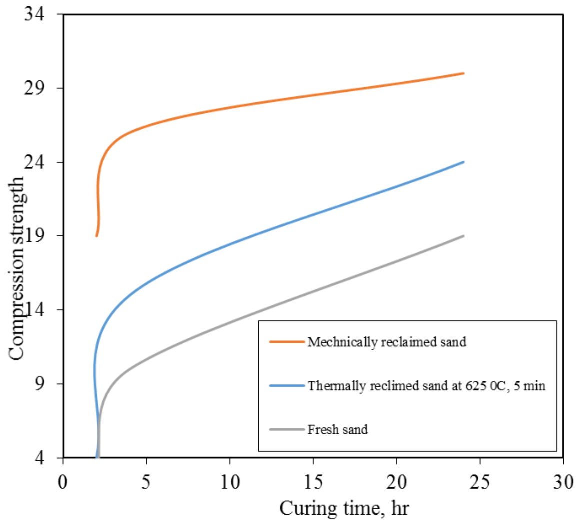


Fig 7 Compression strength of diffrent sands

From the above graph, mechanically reclaimed sand has higher compression strength with more additives while the thermally reclaimed sand with less additives also produced equally competitive or higher than fresh sand. Thermally reclaimed sand at 625 ^{0}C with 5 minutes is competitive source for fresh and mechanically reclaimed sand. Visual observation of these sands shown in Figure 8

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Fig 8. Visual observation of thermally reclaimed, mechanically reclaimed and fresh sand respectively.

IV. CONCLUSIONS

The detailed study on thermal reclamation of used sand (furan resin bonded) was conducted to identify the suitable conditions or optimized temperature and time. Various physical parameters i.e. pH, sulphur, loss of ignition and total gas evolved are measured for samples with different thermal reclamation conditions. It was observed that the normal practice is to burn the chemically bonded sand above 800 ^{0}C which was consuming very high energy and with the studies and experiments conducted in the present work suggests that M, N, K samples are in agreement with the properties examined here. The samples with 600 ^{0}C with 15 min, 625 ^{0}C with 10 min and 15 min are better compatible with the new sand.

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