Wet Reclamation for Improving Properties of Waste Silica Sand from Foundry

Dewi Idamayanti, Ari Siswanto, R. Widodo, Aldy Budhi Iskandar

***Abstract*— Metal casting commonly uses silica sand with water glass as a binder for mold and core. Water glass binder that overlays grain sand was harden by CO2 gas to form silicate bonding. The waste silica sand was not able to be reused as mold and core because its properties changed due to high temperature exposure during casting process that converted silicate bonding become refractory compound. Recently, several methods were developed to recycle waste silica sand. The methods recommended were mechanical, thermal and wet methods. In this research, wet method has been selected to reclaime waste silica sand due to good properties result. The research methodology involved several processes. Lumps of waste silica sand was crushed mechanically then mixed with water at the ratio of 1 : 1 by weight and stirred at the speed of 1400 RPM. The mixing and washing steps have been done gradually until five times. The properties of reclaimed silica sand resulted sintering point over 1300oC, loss on ignition 0.5%, grain fineness number 76.6, and dust content 0.42. Its physical properties comply standard specification of silica sand. The reclaimed sand after fifth washing was observed under SEM and showed that most of sand grain could be separated and it had the angular shape with medium sphericity.**

***Index Terms*— Foundry sand reclamation, Wet reclamation, Silicate sand properties**

I. INTRODUCTION

Metal casting is a process of pouring metal liquid into the cavity of the sand mold or metal molds. Silica sand plays a key role in all metal casting as mold and core. Silica sand is one of three most of sand mold commonly used and widely applied in steel casting [1]. Water glass as the silica sand binder is one of sodium silicate sources. The bonding system of water glass can be harden by CO_2 to form a silicate bridge between silica sand grain (fig 1). This process results solid network linked product. At the same time, carbonate is also formed in silicate bonding. The reaction[2] can be expressed as the equation 1 :

$$Na_2O.nSiO_2.xH_2O + CO_2 \rightarrow Na_2CO_3\, nSiO_2 + xH_2O \quad ..(1)$$

In fact, the chemical hardening of sodium silicate involves three stages, namely the hydration of sodium silicate, the formation of silicate gel and lastly cross linkage of silicate gel to form solid network [4]. Silicate bonded silica sand is widely used in foundry casting because of their characteristics of good moldability, high strength, excellent hot deformability and simple production process [1,4].

The characteristics of silicate bonded silica sand will be affected by high temperature exposure during metal casting, such as nodular cast iron casting needs until 1400°C. While mold and core were exposed in the high temperature, silicate binder will decompose to become refractory compound that has a high modulus in which decrease bonding strength and workable time of mold and core [3,7].

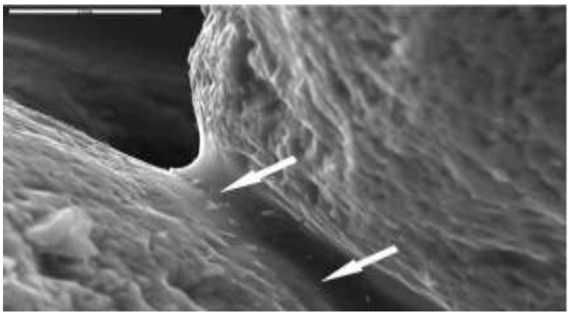

Figure 1. Silicate bridge between sand grain [2]

Recently, alot of quantities of waste silica sand have been generated from the casting process [4]. Sand reclamation is required to treat waste silica sand and improve its properties. It can contribute the energy saving and increase material efficiency. To reduce consumption of new silica sand, reclaimed silica sand can be reused as sand mold or face sand.

Ramana [5] recommended several methods to reclaime silicate bonded silica sand. The methods are dry, wet, thermal, and combined reclamation of three methods. Suitability of specific methods for silicate bonded silica sand reclamation has been studied. Thermal reclamation generally uses for organically bonded sand. Dry reclamation is suitable for hard and brittle binder like silicate bonded silica sand, but it must be completed by pneumatic attrition [6].

In this research, wet reclamation method was selected due to good properties result and enviromental consideration. In this method, water as an eco-solvent dissolve the refractory compounds which contained silicate and carbonate. Fan et al [7] explained that refractory properties of silicate have high water absorption in the atmospheric environmen but carbonate compound has higher solubility in water than silicate one. Fan et al [7] observed that wet reclaimed sand increased de-skinning rate of residual silicate on the silica sand surface and could dissolve in scrubbing solution. He recommended that the reclaimed silica sand can replace new sand to be used as single sand or facing sand so that no waste silica sand is disposed. A new process of wet reclamation followed by biologycally treating was developed by Huafang et al [9]. His investigation showed the increasing of de-skinning rasio with the less water used. Danko et al [9]

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reviewed that wet reclamation is the most efficient method for silica sand containing water-glass hardened by CO_2

The objective of research is to recycle waste silica sand using the wet reclamation, reduce residual binder and result sand properties that comply with a standard specification of mold and core sand. The usage of reclaimed silica sand will enhance the efficiency of silica sand for mold and core.

II. EXPERIMENTAL METHOD

A. Equipments and materials

The equipments used in this research were lump breaker, mixing machine, ceramic boat, sand strength machine, dying oven, furnace, and analytical balance.

The Materials used in the research were waste silica sand from mold and core, deionized water as received without further purification and water glass was obtained from foundry supplier.

B. Wet reclamation process

This research was conducted to reclaime silicate bonded silica sand through several steps as described in fig 2. The lump of waste silica sand was crushed manually by hammer until reach granular size and then screened. Crushed sand was blended with water at the ratio 1 : 1 by weight, then stirred at the speed of 1400 RPM. Subsequently, the mixture was separated by filtering. The sand washing process was repeated until five times. Finally, every separated sand was dried under sunlight exposure and then characterized.

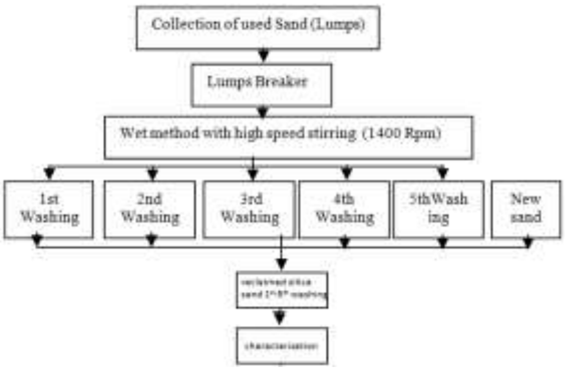

Figure 2. Flow chart of wet reclamation method

Figure 3. lump of waste silica sand (left) and crushed sand (right)

Figure 4. stirring process

C. Characterizations

A small amount of dried reclaimed sand was characterized by sintering point, dust content, grain fineness number and loss on ignition. Furthermore, the properties of reclaimed silica sand were compared to new sand. The testing results were evaluated against the standard specification of silica sand for mold and core.

Likewise, reclaimed sand was observed under scanning electron microscopy (SEM, Hitachi SU 3500, 5kV) to characterize the surface morphology of silica grain. Similarly, elemental analyses on silica grain surface was carried out using energy dispertive X-Ray spectroscopy (EDS, EDAX instruments) to identify and measure residual sodium element.

III. RESULT

A. Wet reclaiming process

Fan et al [4] observed that silicate bonded silica sand have different characteristics based on temperature exposure. The silica sand area that closer to the casting surface can receive heat over 800°C. Silicate binders are burned onto silica particle as thin film, which has a low melting point. The silica sand area that exposed 600 – 800°C partially melted with cracks. Silicate binder have dry and stiff properties. Further away from the casting surface where silica sand temperature between 200 – 600°C, silicate binder has higher bonding strength and difficult to reclaime. The wet reclaiming process of waste silica sand, mainly removed the residual binder on silica grain surface after mechanical breaking. However, most of the residues on silica sand are soluble in water and easily adsorp water [4]. The research carried out wet reclamation until five stages and then determined the optimum washing stages.

As seen in Fig 5, the clarity of filtrate shows the impurity content. Fifth washing resulted the clearest filtrate. Fan et al [4,7] observed that wet reclamation gave better quality than dry reclamation. Herein, quality of reclaimed silica sand was represented by loss on ignition, dust content, sintering point and grain fineness number.

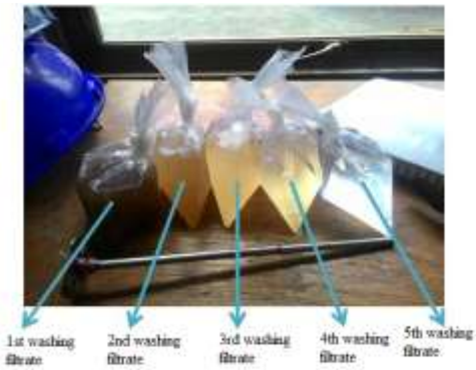

Figure 5. filtrate of washing stages

B. The physical properties

The mechanical properties of mold and core is affected by the physical properties of silica sand, i.e compressive strength, tensile strength and hardness. Table 1 shows the result of loss on ignition of reclaimed silica sand compared to new silica sand. Loss on ignition measures the weight loss or weight gain of sand sample that fired at 982° C. The weight loss due to volatization of organics, i.e. carbon dust, decomposition of inorganic compounds, and weight gain due to oxidation reactions. Refer to standard, LOI limit shall be lower than 0.5%. LOI affect the consumption of silica sand binder. As presented in Table 1, reclaimed silica sand after the second washing fulfill LOI standard.

Table 1. Loss of Ignition (LOI) of reclaimed silica sand

Testing	*Loss on Ignition, %*
New sand	0.31
Reclaimed silica sand after 1st washing	0.50
Reclaimed silica sand after 2nd washing	0.38
Reclaimed silica sand after 3rd washing	0.38
Reclaimed silica sand after 4th washing	0.37
Reclaimed silica sand after 5th washing	0.35

Table 2. Grain fineness number of reclaimed sand

Testing	AFS No
New sand	81.3
Reclaimed silica sand after 1st washing	56.2
Reclaimed silica sand after 2nd washing	57.3
Reclaimed silica sand after 3rd washing	57.2
Reclaimed silica sand after 4th washing	76.9
Reclaimed silica sand after 5th washing	76.7

The purpose of the sieve analysis testing is to determine the particle size distribution and estimate the average sieve size of silica sand using standard testing sieves. Reclaimed sand after the third washing has a bigger grain sand size than new sand. It means that silicate binder is still overlaying grain sand. Reclaimed sand of the fourth washing resulted grain size approach to new sand.

Table 3. Sintering point of reclaimed sand

Testing	Sintering point, °C
New sand	> 1300
Reclaimed silica sand after 1st washing	1200
Reclaimed silica sand after 2nd washing	1250
Reclaimed silica sand after 3rd washing	>1300
Reclaimed silica sand after 4th washing	> 1300
Reclaimed silica sand after 5th washing	>1300

The sintered sand occur at the temperature that sand grain surface begin to bond partially. The sintering point testing is needed to observe how silica sand or other sand withstand during metal casting. Refer to standard, the sintering point shall be over 1250°C for sand that contain silica 96%.

Sintering point was tested on ceramic boat and heated until 1300°C in the furnace. Silica sand that withstands over 1250°C is acceptable for gray cast iron or nodular cast iron casting.

As listed in Table 3, reclaimed sand after the third washing resulted sintering point over 1300°C and fulfilled standard specification for sand molding.

Tabel 4. Dust content

Testing	Dust content %
New sand	0.75
Reclaimed silica sand after 1st washing	0.44
Reclaimed silica sand after 2nd washing	0.34
Reclaimed silica sand after 3rd washing	0.51
Reclaimed silica sand after 4th washing	0.52
Reclaimed silica sand after 5th washing	0.42

The dust content describes the amount of dust in sand which may contain carbon, dead clay and fine size silica. Dust content shall be controlled to prevent sand quality. High dust content affect low sintering point and stimulate casting defect due to air trapped in molding. Table 4 shows that reclaimed sand after fifth washing has lowest dust content. The more reclaimed sand washed, the less dust contains.

C. Morphology of reclaimed silica sand

Scanning electron microscopy was required to observe the surface of reclaimed silica sand covering the shape of sand and residual silicate binder. The observation carried out under 3kV with spot intensity 40% and using the secondary electron detector.

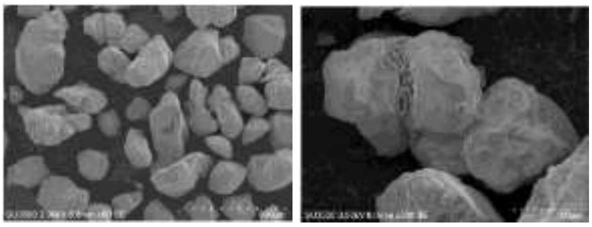

Figure 6. The morphology of waste silica sand

As seen in fig 6, The morphology of waste silica sand tends to be sharp and produces a flat area due to mechanical fracture. In the area around the binder bridge looks a lot of fine particles. Fan et al [4] explained that fine particle of silicate binder was generated as a result of temperature exposure over 800°C.

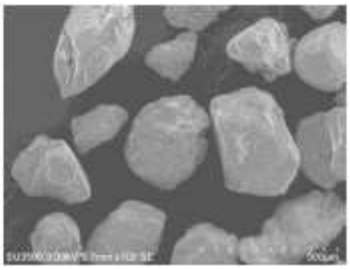

Figure 7. The morphology of new silica sand

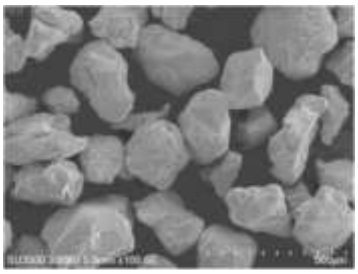

Figure 8. Morphology of reclaimed silica sand after fifth washing

Fig 8 shows that fifth washing of reclaimed silica sand resulted grain shape close to new sand. The most of sand grain was separated completely. The sand grain has the angular shape with medium sphericity.

Figure 9. elemental analysis of silica sand waste by EDS spectrometer

The silica sand waste contained high carbon dust and total sodium. Meanwhile, silicon and oxygen element can be found both on waste and reclaiming silica sand.

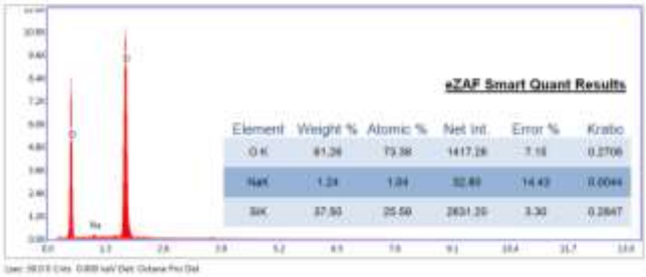

Figure 10. elemental analysis of reclaimed silica sand after third washing by EDS spectrometer

EDS spectrometry was used to detect residual sodium element on silica sand grain. Sodium is a control element to represent Na_2CO_3 in silicate bonding or Na_2O from residual water-glass or Na_2O as a result of high temperature oxidation silicate binder. The accumulation of Na_2O on silica sand as face sand will cause a casting defect [4]. The sodium element content in reclaiming sand decreased from first to fifth washing. In fig 10, the sodium element in reclaimed sand after the third washing was reduced up to 1.24%. Meanwhile, the silica sand waste contained sodium element 19.22 %, as seen in fig 9. The characterizations result showed that wet reclamation process is effective to remove the residual binder.

IV. CONCLUSION

The research result can be concluded that wet reclamation using water washing is effective to improve the properties of the waste silica sand. The reclamation process recommended up to five stages.

Reclaimed sand after fifth washing resulted LOI 0.35%, AFS no 76.7, sintering point over 1300°C and dust content 0.42 %. The morphology of reclaimed silica sand is close to new sand and Its properties fulfilled silica sand standard for mold and core.

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