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Study of the Reclamation of Waste CO_2 Moulding Sand in Foundry Industry

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ABSTRACT

The study of the reclamation of waste CO_2 moulding sands aims to exercise further studies on treatment of CO_2 waste moulding sands and to ensure the final chemical composition of the CO_2 waste moulding sands. The research gives information about the potential of waste sand reclamations. In addition, this research aims to develop SOPs or signs in treatment waste sand.Reclamation process was begun in the crushing of sand lump by hammer and mixing machine reached granular size. The filtered process was done to separate the sand grains from the large size. Then, the washing process of the waste CO_2 moulding sand using detergent solution with variation concentrations of detergent 0.2; 0.3; and 0.4%, respectively. A newand waste silica sand were characterized to study physical and chemical properties. The characterization including grain shape, clay content, and grain fineness number (GFN). The morphology and element content in sands were observed under SEM-EDS instrument.The research shows that the optimum reclamation method is using 0.3% detergent. It results angular grain shape, clay content 2.58%, and GFN 42.16. The morphology and elemental scanning of using 0.3% detergent shows decrement 10.97% of sodium.Based on study was concluded that the detergent wash method is effective to improve the properties of the waste silica sand nearer to new silica sands. The CO_2 moulding sand reclamation can be reused again. In addition, the method of this research can be used in reference of the reclamation of waste CO_2 moulding sand.

Key words: Reclamation, CO_2 moulding sands, detergent wash method

1. INTRODUCTION

4.0 industrial revolution, globalization, innovation, and enhancement of production effectiveness become a challenge for foundry industry. The most important research directions leading to further development of the foundry industry as following: (1) development of new technologies and casting alloys, (2) manufacturing of moulds and cores, (3) preparation of casting materials and composites, (4) technological waste managements, and (5) energy and material efficient technologies [1].Patange, et al. (2013)[2] implemented the research direction of the metal casting sector through technological waste management "sand reclamation". Sand reclamation was treatment of moulding sand so that it regained its original condition and can be reused again, with minimum addition of new sand [3]. Reused of moulding sands required characteristics like new moulding sands, were defined by eight characteristics namely: refractoriness, chemical inertness, permeability, surface finish, cohesiveness, flow ability, collapsibility, and availability/cost. Foundry industry commonly used silica sand with water glass as a binder for mould and core. Water glass binder was sodium silicate sources. The bonding system of water glass can be hardened by CO_2 to form a silicate bridge between silica sand grains. This process resulted linked product; carbonate was also formed in silicate bonding. Strength of bonds between base grains was affected by cohesion forces of bonding bridges and adhesion forces in the assembly water glass surface of silica grains [4]. The advantages of using CO_2 sand moulding were have strong surface, provided great dimensional tolerance and accuracy, moisture was completely eliminated from the sand moulding. However, CO_2 sand moulding difficult to recycle [5].

Several methods to reclaim waste CO_2 moulding sand recommended by [3]. The methods were dry, wet, thermal, and combined reclamation of three methods. Suitability of specific methods to CO_2 sand moulding reclamations has been studied. Fan, at al. (2005) compared dry reusing and wet reclaiming of used sodium silicate sands.Ghosh (2013)[6] carried out thermal sand recycling using a rotary furnace machine at 400 to 800 °C temperatures. The break of grain sand bonds occurred when the sand expanded at that temperature. Stachowicz & Granat (2014)[7] reclaimed bounding of sodium silica sand using a microwave. The method can activate the surface of waste silica grains sands. Reddy & Madhuri (2018)[8] investigated of CO_2 moulding sandsbased on thermal properties of CO_2 silicate moulds. Undayat, et al. (2018)[9] designed the sand recycling system in the small-scale metal casting industry. The recycling system was done manually using a jaw crusher and a hammer mill. However, the properties and possible use of foundry waste havemainly been investigated in the foundry industry [1, 10, 11, 12]. Among the possible reclaiming or reusing methods, there was no agreed single process that the most rational, low cost and high quality. Wet reclamation methods were effective to improve the properties of the waste silica sand [13].

A new wet reclamation technique for CO_2waste mouldingsands was carried out by [14]. Patel reclaimed CO_2waste mouldingsandsthrough detergent wash method. The method improved characteristics of waste mouldingsandsapproached the new silica sand characteristics. The study explained the mechanical effects of CO_2 waste moulding sands, while the chemical effects on the CO_2 waste sand has not been explained. In addition, the research has not yet been explained in detail regarding the composition and standard operational procedure (SOP) of waste treatment. The research aims to exercise further studies on treatment of CO_2waste moulding sands in terms of chemistry and to ensure the final chemical composition of the CO_2 waste moulding sands. The research give information about the potential of waste sand reclamations. In addition, this research aims to develop SOPs or signs in treatment waste sand [22-23].

2. MATERIALS AND METHODS

2.1 Reclamation process

CO_2 waste moulding sands from Politeknik Manufaktur Ceper separated from the other component. The waste sands used in this research was moulding sands directly exposed to heat when pouring process (Figure 1). The lump crushed by hammer and mixing machine reached granular size. The filtered process was conducted to separate the sand grains fromthe large size. Patel et al., (2015)[14] reclaimed sodium silicate bonded CO_2 by detergent wash method. Three containers containing 1 kg of waste sand were prepared for the washing process. In each container was added 1 L of detergent solution with variation concentrations of detergent 0.2; 0.3; and 0.4%, respectively. The mixture of sand were stirred. Finally, every separated sand was dried under sunlight exposure and then characterized.

Figure 1: The lump of CO_2 waste moulding sands

2.2 Characterizations

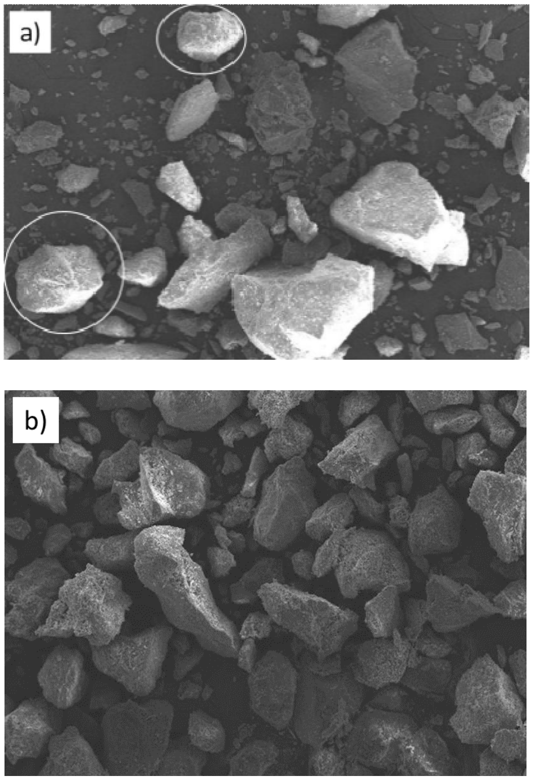
A new sand, CO_2 waste moulding sands without washed and CO_2 waste moulding sands with wash variations were characterized to study physical and chemical properties. The characterization of physical properties including grain shape, clay content, and grain fineness number (GFN). The metallographic microscope used to observe the grain shape, the moisture tester (Serial No: 109610) to analyze clay content in silica sand, and set of standard test sieves mounted on a sieve shaker (Octagon) to observe GFN. The morphology and element content in silica grain was observed under scanning electron microscope and energy dispersive X-ray spectroscopy (SEM-EDS, JED 2300, 20 kV).

3. RESULTS AND DISCUSSION

The aims of sand characterization are to check the consistency of the prepared sand and to determine if the reclamation of waste sand has phisycal and chemical properties to produce good castings[15]. The physical properties of sand depends upon its grain size, grain shape, moisture, and clay contents of the moulding sand . The Grain shape and grain distribution areimportant factors in the selection of sands for the various processes [16].

3.1 Physical Properties

***Sand grain shapes*.**The shape of silica sand grains has a significant effect on the different properties of moulding sands, such as strength and permeability. The classified of sand grain shapes are rounded, sub-angular, angular, and crystal. The observation results using Metallographic Microscope on new sand, waste sand without washing and waste sand with detergent wash appeared the same results, have angular shape. Meanwhile, the observation results using SEM show the difference results. The new sand has an angular and rounded shapes, while waste sand without washing and waste sand with detergent wash have angular shape. It occurred during the crushing process, it is collision between the grains causes the rounded grains will broke (white circle in figure 2.a) and forms an angular. The results of SEM observations are shown in Figure 2.



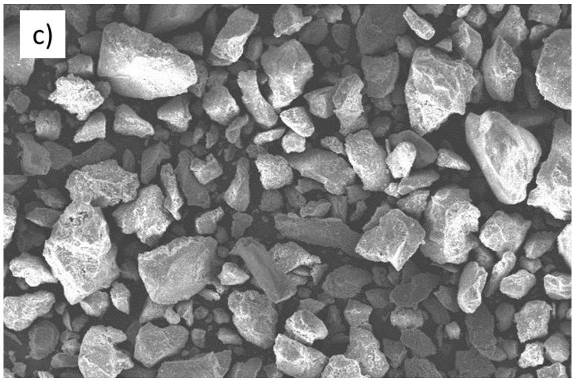


Figure 2: The grain shapes of a) new sand, b) sand waste without washing, dan c) sand waste with washing

The angular grain shapes are most widely used in casting iron, steel and non-ferrous metals. The shape of silica sand grains has effect in amount of binder used in sand moulding. The angular grain shapes provide the greater contact area between grains so need higher amount of binder than sub angular grain shapes. A higher percentage of binder is required to bring in the desired strength in the moulding sand. The greater contact area resulted in narrower cavities and it have high density, so that permeability of angular shape has lower and the strength has higher. Marin & Zupan (2011) [17] explained the basic morphological parameters such as the average diameter and standard deviations of particles, are not enough to explain the difference in strength. Meanwhile, the grain sand shapes were one of the crucial parameters to control the strength in the moulding sand.

*Clay content.*Another component that important in moulding sands was clay content. Clay content testing was carried out to determine clay content of new sands, waste sand without washing (A), and waste sand with detergent washed varying 0.2, 0.3, and 0.4% (B-D), respectively. The reaction of compounds in making moulding sand increase the amount of clay content, it appeared that waste sand without washing has the highest clay content. Recycling using detergent wash method reduces the amount of clay in sand waste, the compound in the detergent solution is able to dissolve the clay compound. The greater of the detergent concentration, the greater clay content decreasing (Figure 3).

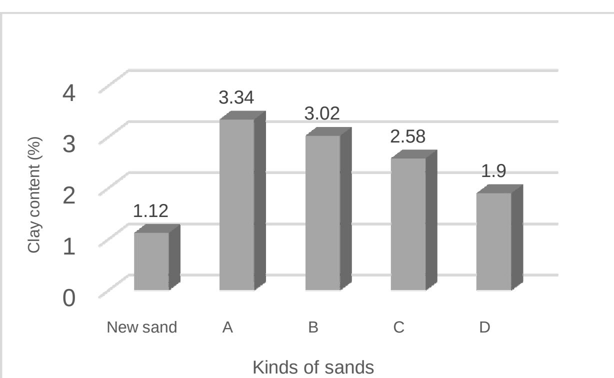


Figure 3: Clay content of treatment variation

The amount of clay content affects the strength in reused of waste moulding sands. The reused of sand waste with higher clay content and without the water addition reduce plasticity so that the formability of sand decrease. Astika, et al. (2010)[18] stated that clay content influences permeability and impression strength. This is due, the clay filled the pores between the sand grains so that the permeability decreased and the strength increased. As seen in figure 3, indicates decrement in clay content and the highest decrement of clay content occurred at 4% washing detergent.The allowed clay content in making moulding sandsare 2-50% with the amount of water content adjusted to clay content. The results of clay content test in this research include in required range of moulding sands.It can be conclude that the sand waste can be reused for the other types of moulding sands. Meanwhile, the reuse of waste sand reclamation for making the CO_2 moulding sand required a minimum of clay content. (Reddy & Madhuri, 2018)[8] and (Ramana, 2015)[3] explained the CO_2 moulding sand does not require clay content.

Sand distribution. The distribution of sand grains have a large bearing upon its strength and other general characteristics [19]. The distribution influences the formation of casting defects that can reduce the productivity. The surface of metal casting became smoother if the used sand is fine grains. In the other hands, the finer of the grainsthe more contact of grain sands. It causesthe lowerpermeability, results casting defects such as gas bubbles. The grain sands with wide range of particle sizes has higher compatibility than narrow distribution. The distribution of CO_2 moulding sands is shown in Figure 4. As seen in the figure it appears that the largest grain size distribution in 420> x> 297 range. This distribution of grain sand due to sand collisions that occur during the recycling process.

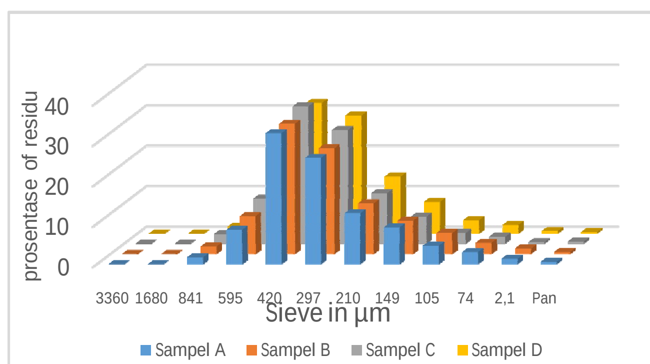


Figure 4: Distribution size of A) waste sand without washing, B) detergent whased0.2%, C) detergent whased0.3%, danD) detergent whased0.4%

The grain fineness number (GFN) of the sand deposit are 40.01. This grade of fineness number is widely applied in CO_2 moulding sands for all types of metal casting either ferrous or non-ferrous alloys [20-21]. Based on the AFS standard specification for moulding sand, the GFN value ranges from 40-45. The sieve test in research results GFN value of waste sand without washing, washed with

0.2%;0.3% and 0.4% detergent are 47.92; 47,37; 42,16; and 44.4 respectively. The grain size of waste sand with detergent washingcoarser due to the occurrence dissolution of fine grain during washing. Meanwhile, waste sand without washing tends to finer. The finer grain sands result narrow inter-cavity spaces cause the low permeability. According to sieve results in the research, waste sand with detergent washed 3 and 4% can be reused due to it on the range in the specified standards.

3.2 Physical Properties

Scanning electron microscopy (SEM) is required to observe the surface shapes and residual silicate binder. As seen in figure 5, the surface of waste sand without washed is covered with many silica-binding residues. The residue is a water glass used in making of CO_2 sand moulding. It appears the morphology of waste silica sand tends to be sharp. The waste sand affect casting defect in reused in moulding sands.

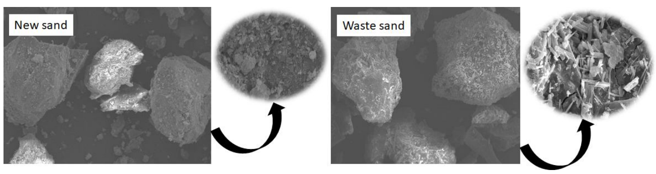
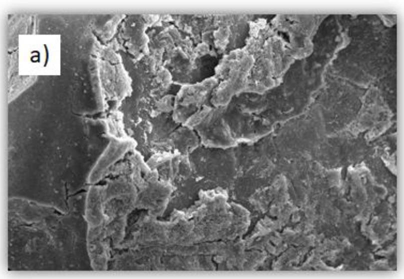


Figure 5: The morphology of new sand and waste sand

The detergent wash methods decreases residue found on the surface of the sands. Chemically, the chemical reactions that occur in CO_2 sand moulding written in Eq. (1).

$$Na_2SiO_2.X\ H_2O + CO_2 \rightarrow SiO_2.X\ H_2O + Na_2CO_3 \quad (1)$$

The reaction has transformed the bonding structure of silica sand, in this case occurred interatomic bonding and causes difficult to break-down. The use of the crushing machine is to release the silica bonds of the product from the CO_2 process and detergent washing to release Na_2CO_3 in waste sand [14]. Detergents contain surfactant compounds. The surfactant has a hydrophobic group and a hydrophilic group in the other hand. This hydrophilic surfactant group dissolves water glass residues and releases Na_2CO_3 in waste sand (Figure 6).



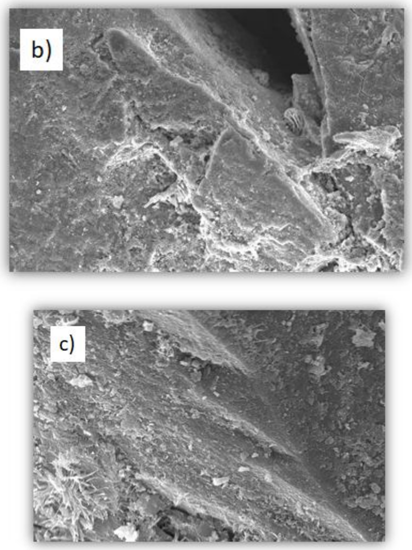
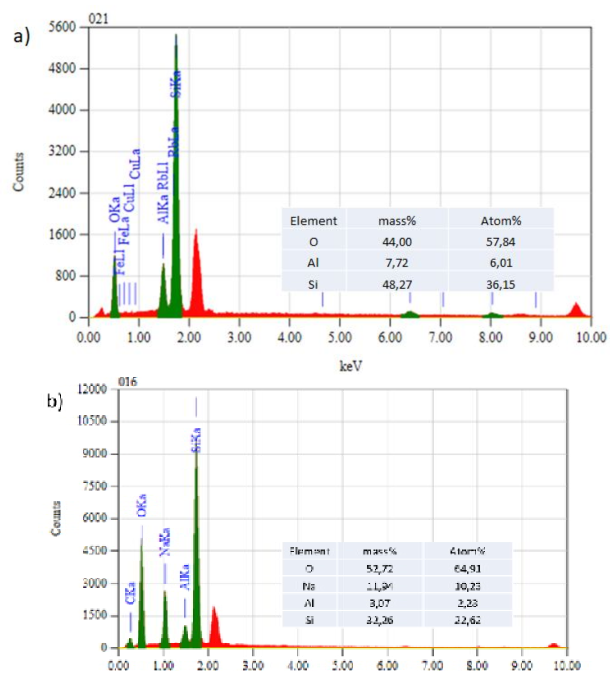


Figure 6: The morphology of sandreclaimation, a) 0.2 %, b) 0.3 %, dan c) 0.4 % of detergent

To ensure the SEM results carried out characterization using EDSinstrumnet. EDS is used to detect sodium residues. Sodium is present in the Na_2CO_3 compounds from water glass residues. As seen in Figure 7, the sodium content in the new sand can be neglected because it's so little. In making of CO_2 sand moulding, amount of water glass is added and produce a compound containing sodium (shown in Figure 7b). The accumulation of sodium result casting defects. The SEM EDS characterization show the reclamation using detergent washmethod reduce sodium in waste sand up to 10%.



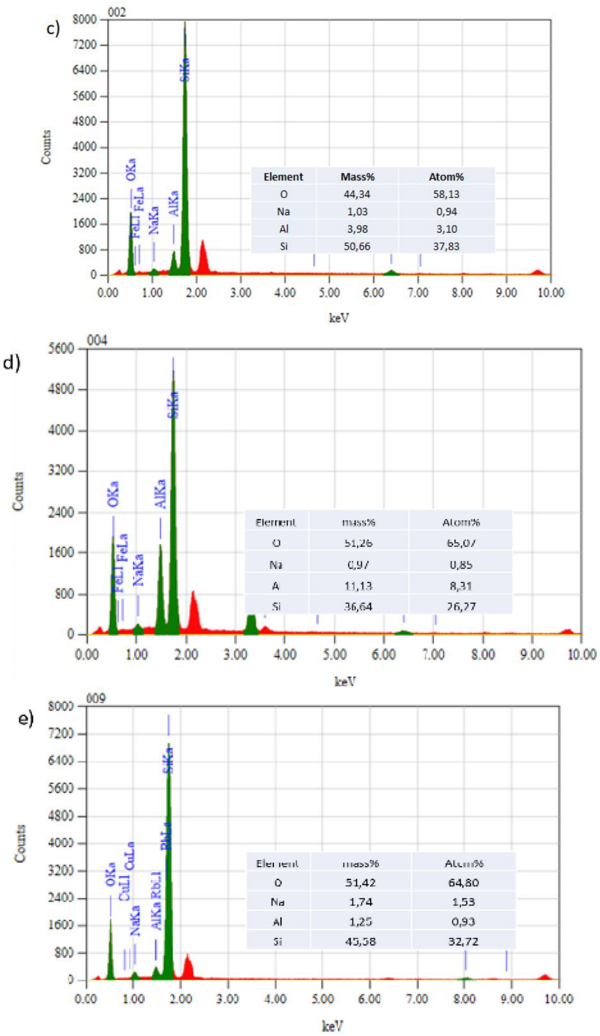


Figure 7: Element contentof a) new sand, b) waste sand without washing, c) detergent whased0.2%, d) detergent whased0.3%, dane) detergent whased0.4%

The highest sodium decreased appears in 0.3% detergent variation. The washing using 2% detergent reduce sodium up to optimum concentration. After passing the saturation point, adding the amount of detergent not affect the sodium decrease. The reclamation wash method using 0.3% of detergent is optimum methods. According to SEM EDS characterization shows that reclaimed silica sand using this method results properties close to new sand. It is concluded that the waste sand reclamation using detergent wash method has potential to be reused and.

4. CONCLUSION

Based on sstudy of the reclamation of waste CO_2 moulding sand was concluded that detergent wash method is effective to improve the properties of the waste silica sand nearer to new silica sands. The optimum reclamation method is using 0.3% detergent, it results angular grain shape, clay content 2.58%, GFN 42.16. The morphology and elemental scanning of using 0.3% detergent shows decrement of sodium 10.97%.

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