

Grain Size Variations of Reclaimed CO₂ Sand Mold on Hardness and Metal Surface Roughness

Sabtun Ismi Khasanah^a, Akhmad Nurdin^b, Tri Daryanto^a

^a Department of Foundry, Politeknik Manufaktur Ceper, Batur, Tegalrejo, Klaten Regency, Central Java, Indonesia 57465

^b Department of Engineering Design Manufacturing, Politeknik Manufaktur Ceper, Batur, Tegalrejo, Klaten Regency, Central Java, Indonesia 57465

e-mail: sabtunismikhasanah@gmail.com, nurdin@polmanceper.ac.id, anto.tridaryanto@gmail.com

Kata kunci:

Pencetakan limbah
CO₂, Reklamasi,
Ukuran butir,
Kekasaran
permukaan.

ABSTRAK

Penelitian mengenai reklamasi limbah cetakan pasir CO₂ berpeluang untuk meningkatkan produktivitas. Penelitian ini dilakukan untuk mempelajari lebih lanjut tentang potensi cetakan pasir CO₂ yang direklamasi. Pengaruh ukuran butir dari cetakan pasir CO₂ yang direklamasi terhadap kekerasan dan kekasaran permukaan logam dianalisis. Selain itu, perbandingan analisis kualitas pengecoran dilakukan antara produk yang menggunakan pasir baru dan cetakan pasir CO₂ reklamasi. Cetakan pasir CO₂ dihancurkan dan kemudian diayak dengan menggunakan ayakan 12, 25, dan 40 *mesh*. Butiran limbah pasir direklamasi melalui proses pencucian dengan detergen. Karakterisasi SEM-EDS dilakukan untuk mengetahui unsur-unsur yang terkandung. Kekerasan produk hasil pengecoran diuji dengan menggunakan metode Rockwell dengan beban 981 N. Sementara itu, kekasaran permukaan logam di karakterisasi melalui *Roughness Test* dan identifikasi visual dengan menggunakan standar JIS 82. Berdasarkan hasil karakterisasi SEM-EDS, ketiga variasi pasir CO₂ hasil reklamasi berpotensi untuk digunakan kembali. Kualitas kekerasan dan kekasaran permukaan logam dari pasir CO₂ hasil reklamasi dengan variasi ukuran 25 *mesh* mendekati kualitas produk pengecoran dengan menggunakan cetakan pasir baru.

Keyword:

CO₂ waste moulding,
Reclaimed,
Grain size,
Surface roughness.

ABSTRACT

Studies on reclaiming CO₂ sand mould waste have the opportunity to increase productivity. This research was conducted to learn further about the potential of reclaimed CO₂ sand moulds. The effect of the grain size of the reclaimed CO₂ sand mould on the hardness and metal surface roughness was analyzed. In addition, a comparison of casting quality analysis was carried out between products using new sand and reclaimed CO₂ sand moulds. The CO₂ sand moulds were crushed and then sieved using 12, 25, and 40 mesh sieves. The sand waste grains were reclaimed through a detergent washing process. SEM-EDS characterization was carried out to determine the elements contained. The hardness of the casting product was tested using the Rockwell method with a load of 981 N. Meanwhile, the metal surface roughness was characterized through the Roughness Test and visual identification using the JIS 82 standard. Based on the results of the SEM-EDS characterization, the three variations of the reclaimed CO₂ sand have the potential to be reused. The quality of the hardness and metal surface roughness of the reclaimed CO₂ sand with a 25-mesh size variation is close to the quality of the casting product using a new sand mould.

1. INTRODUCTION

Metal casting is a part of the manufacturing process that produces products. Typically, the products have complex shapes or materials that are difficult to process through standard machining. To create a quality casting product, it is necessary to give attention to the following factors: the casting, the composition

of the raw material, the quality of the moulding sand, the melting and pouring system, and the fettling system.

Sand is a component that is often used in the metal casting industry. This sand is used as a mould for molten metal. The use of this sand is due to its properties: it can be moulded easily, has resistance to high temperatures, and has a relatively small reaction to metal materials. This sand can be moulded to have sufficient mechanical strength to withstand the metallostatic stresses of the metal. The use of sand moulds affects metal properties in terms of hardness and metal shape [1]. The raw materials for making sand moulds can be divided into two groups: the main ingredients consisting of sand, binding agent, and water. And the others are additives, such as graphite, charcoal powder, flour, or vegetable oil. These materials are intended to improve the mechanical and physical properties of the mould.

The CO₂ sand mould is one of the sand moulds that is often used in the metal casting industry. This mould uses a water-glass chemical binder that contains sodium silicate hydrate (Na₂Si₄O₉5H₂O). The sand mixture is put into the core box and then reacts with CO₂ gas so that it becomes solid and hard [2]. The hardness of the moulds produced by using fiberglass is high and difficult to deform. This is the weakness of the CO₂ sand mould, namely the crushability and poor recyclability, which results in this waste being thrown away and not being utilized. The continuous use of CO₂-moulded sand can result in an increasingly abundant amount of moulding sand waste. Waste that is not utilized will have a negative impact on the environment [3].

Efforts to reduce the environmental impact of moulding sand waste include its use in the manufacture of concrete [4], the manufacture of ceramics [5], and reuse as a mould in the metal industry. The recycling of foundry waste can increase the efficiency of the production process. Recycling, according to the AFS 4S definition (Sand Reclamation and Re-use Committee), is the physical, chemical, or thermal treatment of waste sand so that it can be reused without significantly reducing its original properties.

Sand recycling requirements, according to Patange et al. (2013) [6], are: (1) can remove all lumps of sand, and the coarse recycled sand results in a rough casting surface; (2) can restore the clay content to an acceptable level; (3) the quality of recycled sand is close to that of new sand; and (4) the quality, appearance, and finishing of products made from recycled sand should be almost the same as that of new sand. Patange et al. (2013) explained the reasons for sand recycling, including (1) economic factors; the foundry industry wants to reduce the total cost of production, which includes production costs, transportation costs, and disposal costs. Sometimes companies have to pay a waste disposal fee. (2) Environmental factors: it is becoming more and more difficult to dispose of significant quantities of material into the ground. (3) Technical factors: reclamation is of interest in that, in some cases, binders and catalysts may be reduced in reclaimed sand. There are some indications that better castings can be made when rather large variations in impurity levels and screen analysis are minimized in an enclosed reclaimed sand loop

The reclaiming sand system is generally divided into three: thermal reclamation, dry reclamation, and wet reclamation. The thermal reclamation system is especially suitable for organically bonded sand. The weakness of this thermal system is that the process requires a lot of energy. Dry reclamation systems use mechanical principles to remove clay and organic layers. This system needs to achieve the level of cleanliness achieved with other systems. A wet reclamation system based on scrubbing can clean the sand. The researchers developed these three recycling systems to solve the problem of sand and mold waste. Ghosh, A. [7] recycles using a crusher to break up lumps of sand and a dust collector to pull out the fine binder. The results of this study indicate that this process cannot remove all binders, so to keep the LOI within limits, it is necessary to add new sand of about 10 to 20%. Ghosh also recycles sand thermally using a rotary furnace at a temperature of 400 to 800 °C. The breaking of bonds in the sand grains occurs when the sand expands at that temperature.

Stachowicz and Granat [8] recycle sand that is bound to sodium silicate using a microwave. This method makes it possible to activate the surface of silica grains from foundry sand waste. Undayat, Ruskandi, and Hidajatullah [9] designed a sand recycling system in the small-scale metal foundry industry to increase cost efficiency and reduce waste. Another method of CO₂ process mould waste recycling is carried out by Patel, Oza, and Pandya [10]. Patel et al. recycle waste moulding sand using the CO₂ process with the detergent washing method. This method is able to improve the characteristics of sand approaching new sand.

Saputra et al. [11] analyzed the hardness of aluminium castings with variations in the grain size of the moulding sand with lost-foam casting. Based on the results of the research conducted, it appears that the larger the sand mesh size, the higher the hardness value. Ahmadi, N [12] varied the time of the sandblasting process and the size of the sand grains used for surface hardness. From the results of the photos, the largest surface abrasion of the material occurs at a grain size of 40 mesh. The effect of water-glass-bonded recycled sand mould on the metal surface of the foundry is investigated by Muttahar et al. [13]. Products are characterized through visual identification and a roughness test using standard JIS B 0659 (Tsai & Tseng, 1999), which is done after going through the sandblasting process. This research was conducted to find out more about the potential for the reuse of recycled CO₂ sand mould waste. The effect of the grain size of the recycled waste sand on the hardness and metal surface was analyzed in this study. In addition, a comparison of casting quality analysis will be carried out between products using new sand moulds and recycled CO₂ sand moulding waste.

2. METHODS

The sand waste used in this study came from sand mould waste belonging to the Ceper Manufacturing Polytechnic in Klaten. The waste sand is pounded using a mortar and then crushed using a mixer machine. Waste sand that has been finely sieved with a 12-mesh sieve, followed by washing using detergent. The foam left in the sand is rinsed with water until the foam disappears. Finally, the sand dried in the sun.

SEM characterization was carried out on new, non-recycled, and recycled sand. All three types of sand are used to make sand moulds. FC25 material is cast into the sand mould that has been made. The cast products are characterized by hardness and roughness through the Roughness Test and visual identification using the JIS 82 standard, which is carried out after passing through the sandblasting process. The characterization results are then used to compile the analysis and conclusions.

3. RESULTS AND DISCUSSION

3.1 SEM-EDS Characteristics

Research conducted by Khasanah et al. [14] showed that CO₂-molded sand waste has a reasonably high Na content. There was a decrease in Na content when reclaiming using the detergent washing method. Washing detergent dissolves water glass residue and releases Na₂CO₃ in waste sand. The results of the SEM characterization of grain size variations in this study showed low levels of Na. Na content in the reclaimed sand was close to the new sand. Based on the results of the SEM characterization of the grain size variations of reclaimed CO₂ sand, the three reclaimed moulding grains of sand have the potential to be reused for metal casting. The SEM characterization was shown in Figure 1.

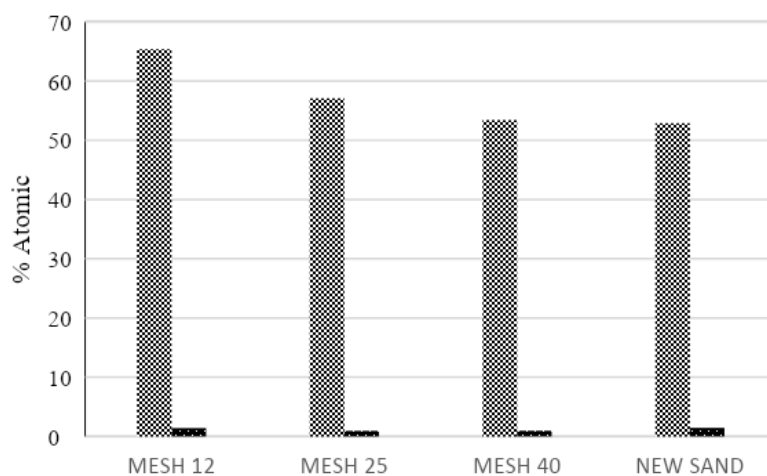


Figure 1. SEM and EDS characteristics of the grain size variation of reclaimed sand and new sand

3.2 Hardness Test

The hardness test carried out in this study aims to compare the quality results of cast products using new sand moulds and reclaimed CO₂ sand moulds. Hardness test using the Rockwell method with a load of 981 N and using a 1/16" steel ball. Each cast object with a variation in mesh size is tested by the Rockwell Method for as many as five points. The hardness test results are in Table 1 and are shown in Figure 2 as a graph of the correlation between grain size variations and hardness.

Figure 2 shows the effect of comparing grain size variation to casting hardness. Based on the JIS G 5501 standard (1995), the hardness of the four cast products corresponds to the FC 250 hardness standard, which is below 241 HB (100 HRB). The casting products using reclaimed waste sand moulds have a hardness below that of those cast using new sand moulds. Reclaimed sands have undergone a crushing process that causes the shape of the sand to change. The sand, which was initially round, becomes an angular shape. If this angular sand is used to make moulds, the hole space between the sand that is formed will be larger than when using a round type of sand. The whole space of sand also determines the cooling rate of the castings. The round shape has a small contact area between the grains, so the hole formed is large and the permeability increases. As a result, the air circulation is getting bigger, and the heat transfer rate is getting bigger, increasing metal hardness. The results of research conducted by Siagian et al. [15] concluded that the greater the permeability of the sand mould, the greater the hardness of the casting product.

Table 1. The result of hardness test using Rockwell Method

mesh	point					HRB (average)
	1	2	3	4	5	
12	92,01	92,93	93,10	93,13	93,05	92,844
25	93,61	93,53	93,97	93,64	93,83	93,716
40	92,98	92,39	92,25	92,42	92,54	92,516
New Sand	95,07	94,95	94,93	94,96	94,95	94,972

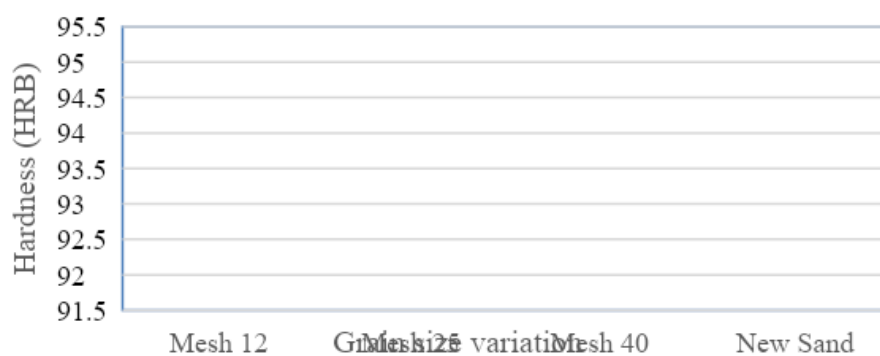


Figure 2. Correlation of sand grain size variation to hardness

The correlation between sand grain variation and roughness is presented in Figure 3. The highest metal surface roughness is obtained at a grain size variation of 25 mesh. There is a correlation between the value of roughness and hardness. The increasing hardness value is linear with the roughness value. These results follow research conducted by Sigit Gunawan & Sigit Budi Hartono [16]. The coarseness of silica sand causes the hardness to increase, but the tensile strength tends to decrease. Based on the quality of the metal surface roughness values and the hardness of the recycled sand, the variation of mesh size 25 is close to the quality of the castings using a new sand mould.

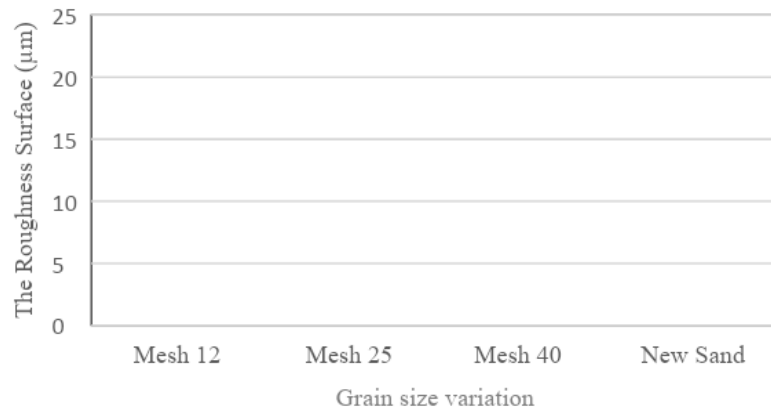


Figure 3. Variation of sand grain size on metal surface roughness

4. CONCLUSION

Based on the results of tests and analysis, the conclusions of this study are as follows:

1. The result of SEM characterization shows that the three variations of the recycled sand grain size have the potential to be reused for metal casting.
2. The quality of the metal surface roughness and the hardness of the recycled sand with a mesh size variation of 25 are close to the quality of the castings using a new sand mould.

REFERENCES

- [1] D. Haryono, "Pengaruh Jenis Pasir Cetakan Terhadap Produk Pengecoran Aluminium Dengan Metode Lost Foam Casting," Universitas Muhammadiyah Surakarta, 2019.
- [2] J. Mitterpach, E. Hroncov, J. Ladomerský, and K. Balco, "Environmental evaluation of grey cast iron via life cycle assessment," *J. Clean. Prod. J.*, vol. 148, pp. 324–335, 2017, doi: 10.1016/j.jclepro.2017.02.023.
- [3] M. M. Khan, M. Singh, S. M. Mahajani, G. N. Jadhav, and S. Mandre, "Reclamation of used Green Sand in small scale foundries Authors:," *J. Mater. Process. Tech.*, pp. 1–35, 2018, doi: 10.1016/j.jmatprotec.2018.01.005.
- [4] R. Siddique and G. Singh, "Resources , Conservation and Recycling Utilization of waste foundry sand (WFS) in concrete manufacturing," *Resources, Conserv. Recycl.*, vol. 55, no. 11, pp. 885–892, 2011, doi: 10.1016/j.resconrec.2011.05.001.
- [5] A. Coz, J. R. Viguri, and A. Andrés, "Recycling of foundry by-products in the ceramic industry : Green and core sand in clay bricks," *Constr. Build. Mater.*, vol. 27, no. 1, pp. 97–106, 2012, doi: 10.1016/j.conbuildmat.2011.08.022.
- [6] G. S. Patange, M. P. Khond, H. J. Rathod, and K. B. Chhadva, "Investigation of foundry waste sand reclamation process for small and medium scale indian foundry," *Int. J. Ind. Eng. Technol.*, vol. 3, no. 1, pp. 1–6, 2013.
- [7] A. Ghosh, "Modern Sand Reclamation Technologies for Economy , Environment Friendliness and Energy Efficiency," in *Transactions of 61st Indian Foundry Congress*, 2013, pp. 1–5.
- [8] M. Stachowicz and K. Granat, "Possibilities of reclamation microwave-hardened molding sands with water glass," *Arch. Metall. Mater.*, vol. 59, no. 2, pp. 757–760, 2014, doi: 10.2478/amm-2014-0127.
- [9] D. F. Undayat, C. Ruskandi, and M. N. Hidajatullah, "Perancangan Sistem Daur Ulang Pasir Pada Industri Pengecoran Logam Skala Kecil Untuk Peningkatan Efisiensi Biaya Dan Pengurangan Limbah," *J. Teknol. Terap.*, vol. 4, no. 1, pp. 55–62, 2018.
- [10] D. R. Patel, M. V. Oza, and M. V. Pandya, "Reclamation of Sodium Silicate Bonded CO 2 Sand by Detergent Wash Method," *Int. J. Eng. Technol. Manag. Appl. Sci.*, vol. 3, no. Special Issue, pp. 156–161, 2015.
- [11] W. A. Saputra, M. Balfas, and M. H. Asiri, "Analisis Kekerasan Coran Aluminium dengan Variasi

- Besar Butir Pasir Cetak," *Teknologi*, vol. 18, no. 1, pp. 1–5, 2018.
- [12] N. Ahmadi, "Effects Of Grains Size And Sandblasting Duration To The Surface Hardness Of The Casting Product," in *Prosiding Seminar Nasional Teknologi Informasi dan Kedirgantaraan : Transformasi Teknologi untuk Mendukung Ketahanan Nasional*, 2018, vol. IV, pp. 1–6.
- [13] M. I. Z. Muttahar *et al.*, "Pengaruh Cetakan Pasir Daur Ulang Berpengikat Waterglass Terhadap Permukaan Logam Hasil Pengecoran," *Flywheel J. Tek. Mesin Untirta*, vol. IV, no. 1, pp. 39–44, 2018.
- [14] S. I. Khasanah, N. R. Sesunan, and H. Abdillah, "Study of the Reclamation of Waste CO₂ Moulding Sand in Foundry Industry," *Int. J. Emerg. Trends Eng. Res.*, vol. 8, no. 9, pp. 5454–5459, 2020.
- [15] S. J. Siagian, I. K. Gede, C. Istri, and P. Kusuma, "Pengaruh Permeabilitas Cetakan Pasir dan Penambahan Silikon (Si) pada Proses Pengecoran Terhadap Kekerasan , Porositas dan Struktur Mikro Alumunium Silikon (Al-Si)," *J. Ilm. Tek. Desain Mek.*, vol. 6, no. 4, pp. 305–310, 2017.
- [16] Sigit Gunawan and Sigit Budi Hartono, "Variasi Ukuran Pasir Cetak terhadap Kekerasan dan Kekuatan Tarik Coran Scrap Piston Sepeda Motor," *Tek. Mesin*, vol. 15, no. 1, pp. 10–20, 2015.