

Porosity and Microstructure Analysis in Aluminum Waste Pieces

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Abstract. Aluminum Waste Pieces (AWP) is aluminum waste from the results of kitchen equipment craftsmen in Panti District, Jember Regency, which can be used as raw materials for metal casting into manufacturing products. This AWP is melted to be recycled and thrown into bars. In this study discussed the analysis of ingot porosity from AWP and microstructure observation. Porosity analysis is performed to determine defects in clotting caused by vacancies because metallic liquids are unable to fill compressed areas during volume shrinkage and release of dissolved hydrogen gas during compaction. The waste used is 1-10 cm remaining pieces with a thickness of 0.5-5mm. AWP is casted using the capacity of a three-liter stove container. Another benefit of this research is recycling AWP as raw material for making ingots. The purpose of this study is to determine the level of AWP. The results of this study are remelting or re-casting causes high porosity with an average porosity percentage value of 43.22% for 43 g cluster, 41.85% for 48 g, and 40.55% for 49 g cluster. This aluminum casting ingot has not been used for construction materials, but can be used for other metal coating processes to inhibit corrosion.

Keywords: AWP, Microstructure, Surface, Picnometri.

1. Introduction

Aluminum is a lightweight metal with 2,7 grams / cm³ of density or about 1/3 of the density of iron (7.83 g / cm³) and copper (8.93 g / cm³) which has corrosion-resistant properties, formability, and includes heat conductors and good electricity. Corrosion-resistant properties of aluminum are obtained from the formation of an aluminum oxide layer from the aluminum surface. This oxide layer is attached firmly and tightly to the surface, and is stable (does not react with the surrounding environment) so that it protects the inside of the aluminum itself.^[1]

Aluminum and its alloys are used in various fields, not only for household appliances but also for material needs in the manufacturing industry as automotive, health, construction, electrical and maritime equipment and various other aluminum components. Aluminum has a relatively cheaper price than copper, this makes aluminum the main choice in the manufacture of household appliances, so that in the production process produces a lot of waste. Not all types of aluminum can be given heat treatment, one of them is pure aluminum such as Aluminum Waste Pieces (AWP). Utilization of aluminum waste by remelting and casting indirectly reduces its mechanical properties due to repetition of the recycling cycle and production.^[2]

The use of waste is very necessary for the efficiency of the main raw material (raw material) to be processed into new products that have a selling value. Waste from household appliances in Panti Subdistrict is in the form of scrap metal aluminum with the current condition of waste being sold directly without being recycled into new products. Waste craftsmen in the form of Aluminum Waste Pieces (AWP) (small pieces of Aluminum plate) thickness of 0.5 - 5 mm with a size of 0.5-10 cm, this waste can be used as raw material for aluminum metal castings.

The metal casting technology used in this research is casting technology with a crucible furnace. Casting technology using a furnace is one of the oldest manufacturing technologies and is still widely used in the industry because it is capable of producing complex and highly economical components with high productivity. However, the problem that often arises is the presence of defects from casting or castings, which can affect the characteristics and mechanical properties of the castings. These problems are shrinkage, gas porosity and structure micro, but what often happens is the shrinkage and porosity of the gas that appears in the castings from the re-casting process.^[3]

Porosity and shrinkage are major defect problems resulting from metal casting. Porosity can occur due to trapping gas bubbles in the molten metal when poured into the mold ^[4]. The existence of this porosity defect will have an influence on the quality of the casting products, one of which is material properties. With the presence of porosity, if the cast gets an operational load, the porosity will become the center of the stress so that the crack will appear more easily in the pores. Therefore, it is necessary to conduct a study that aims to determine the porosity level of the material from remelting or re-casting of AWP that can be used as a reference.

Research on re-casting (remelting) has been carried out by other researchers including Purnomo Researching materials that have been studied are Aluminum alloy 320 (72.37% Al, 11.39% Si, 6.82% Mg, 2.77% Cu), by melting the aluminum alloy 320 and pouring it into a metal mold. Casting was repeated three times, and castings were then made of tensile test specimens and impact tests. The results of the tests carried out explained that re-casting would reduce the tensile strength, and impact strength of the material.^[5]

Fasya and Iskandar utilize recycled aluminum waste in the form of used cans, used alloy wheels and some aluminum-made engine components to be recycled and casted, the results of this study have a 14% melt loss percentage for alloy wheels, 18% canned waste, with each principle 10.92% and 11.94% while engine block waste is 7.16%. ^[6] Based on the background above, this study discusses the AWP meter porosity analysis to be recycled into aluminum ingots, which is then analyzed by microstructure on surface ingots. The type of furnace used is the crucible furnace.

2. Experimental procedure

The research method that will be used is true experimental research. The material used is aluminum waste material from the rest of the craftsmen in Suci Village, Panti District, Jember Regency with 1100 series. The aluminum content for unalloyed aluminum or 1100 series is not made by the purification process so it does not contain 100% aluminum. The other constituent content is silicon (Si) around 0.010% or more.(Table 1)^[5]

Table 1. Chemical composition of Aluminum 1100

Mass concentration of the element, in wt.%, AA standart		
Al	Be	Cu
>= 99.00	<= 0.0008	0.05 - 0.20
Si+Fe	Zn	Mn
<= 0.95	<= 0.10	<= 0.05

For casting equipment that is prepared are sand molding scheme, Crucible melting furnace, Upper stove, Bottom stove, bottom stove rail, kowi, high pressure resistant flexible pipe, hot water tub, digital thermometer, ladle, fireproof gloves, clamp. Remelting is carried out for ± 15 minutes until it melts with pouring temperature of 700°C.

Seen in **Figure 1**, in the research steps, AWP material is ready to be merged (remelting). AWP is cut into small pieces to facilitate fusion and control of furnace volume. Before being put into a metal smelting kowi, the following steps are taken:

- the furnace is heated with a burner with LPG fuel;
- check the temperature of the furnace, if it is above 600 °C, enter AWP into kowi;
- check if the AWP has melted, then measure the temperature again, make sure it's as big as 700 °C;

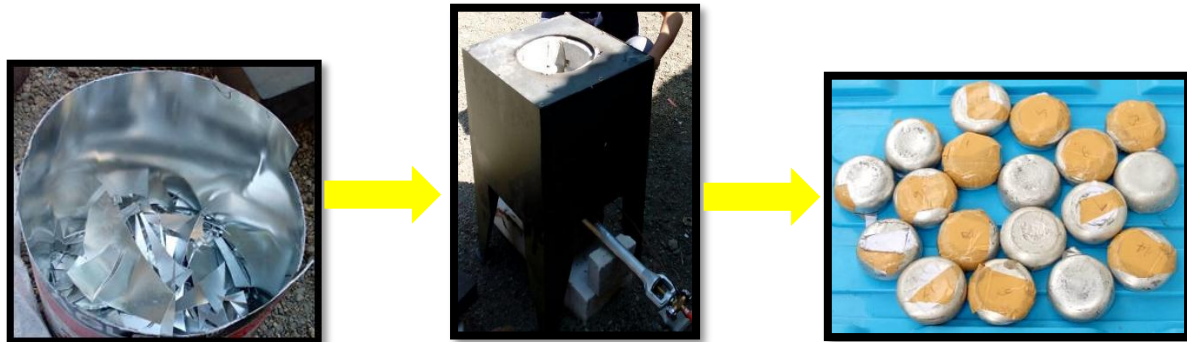


Figure 1. AWP smelting and casting process

Furthermore, in this research, AWP after liquefying at a temperature of 700°C, then poured into a metal mold which was previously heated at a temperature of 150°C and coated with graphite powder. After that the molten aluminum is cooled in air for 10 minutes, until it is then disassembled from the metal mold. After that, castings ingots were tested for porosity using picnometry method with Archimedes principle, which is by calculating the percentage of porosity contained in the test specimen by comparing the density of the sample or apparent density with the theoretical density and true density by using equation 1. ^[7] While the number of specimens used for porosity testing was 30.

$$\% P = \left(1 - \frac{\rho_s}{\rho_{th}}\right) \times 100\% \quad (1)$$

where:

% P = Percentage of porosity (%)

ρ_s = Apparent density (g/cm³)

ρ_{th} = True density (g/cm³)

Apparent density can be measured by weighing specimens outside water and in water as shown in **Figure 2**. below.

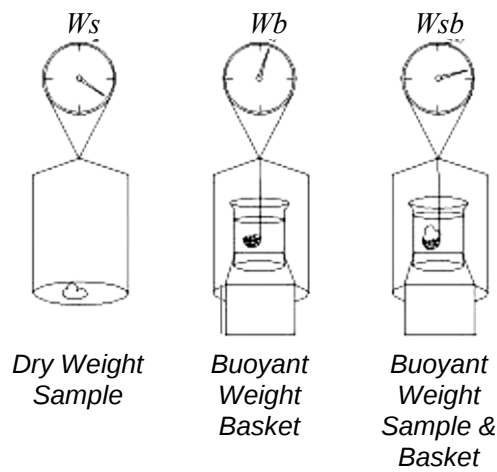


Figure 2. Weighing schemes for apparent density testing

Microstructure testing is carried out in the middle section of the specimen to observe the specimen surface. After that the results of the photo were observed whether there was porosity. The samples for investigations were off the following shape:

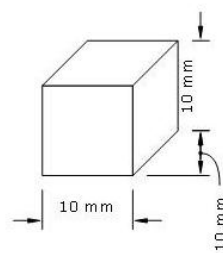


Figure 3. Dimensions of the cubical sample types used for investigations

3. RESULTS AND DISCUSSION

3.1 Porosity Test

From AWP remelting specimens in ingot form, tests were performed to determine the porosity values in the specimens. Porosity testing aims to determine and measure the presence of cavities in castings specimens. The retrieval of porosity test data by density testing using the pycnometry method presented in **Table 2**.

Table 2. Test results of AWP material porosity

Cluster	$\bar{X} W_s$ (g)	$\bar{X} W_{sb}$ (g)	$\bar{X} W_b$ (g)	$\bar{X} \rho_s$ (g/cm ³)	$\bar{X} \% \text{porositas}$
Cluster 47 g	47,63	36,25	19,70	1,53	43,22
Cluster 48 g	48,49	37,29	19,70	1,57	41,85
Cluster 49 g	49,48	38,34	19,70	1,61	40,55

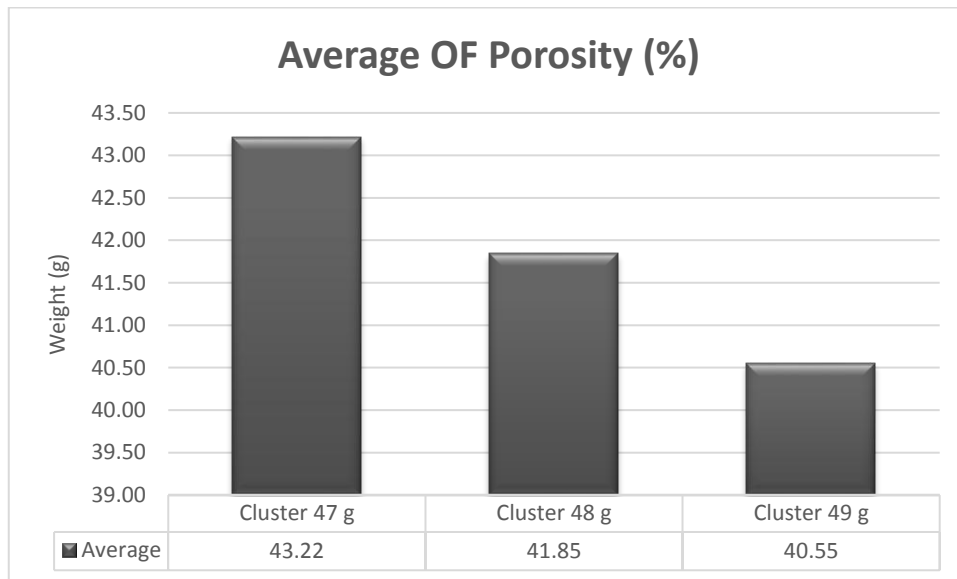


Figure 4. Result of porosity test

1. From porosity testing as shown in **Figure 4**, the results showed that the re-casting or remelting on AWP would have an average porosity percentage of 43.22% for 43 g cluster, 41.85% for 48 g, and 40.55% for cluster 49 g.
2. One of the causes of porosity is hydrogen gas trapping during the freezing process. Freezing starts from metal parts that come into contact with the mold, where the crystal nucleus begins to grow and the crystal grains extend.^[8] As shown in **Figure 5**.

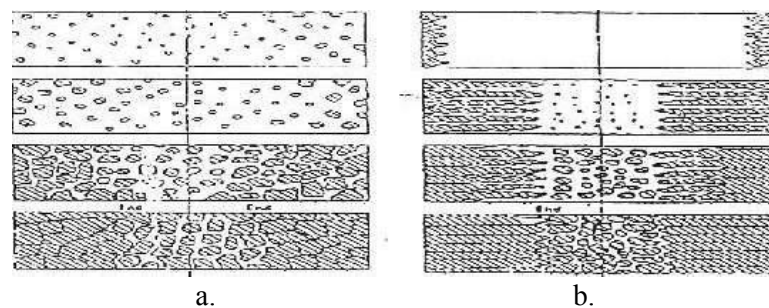


Figure 5. Schematic cast freezing rate: (a) long freezing rate, (b) freezing rate fast

3.2 Microstructure

Microstructure testing in this study aims to ensure porosity after remelting the AWP. Specimens used in microstructure testing look like **Figure 6** below.

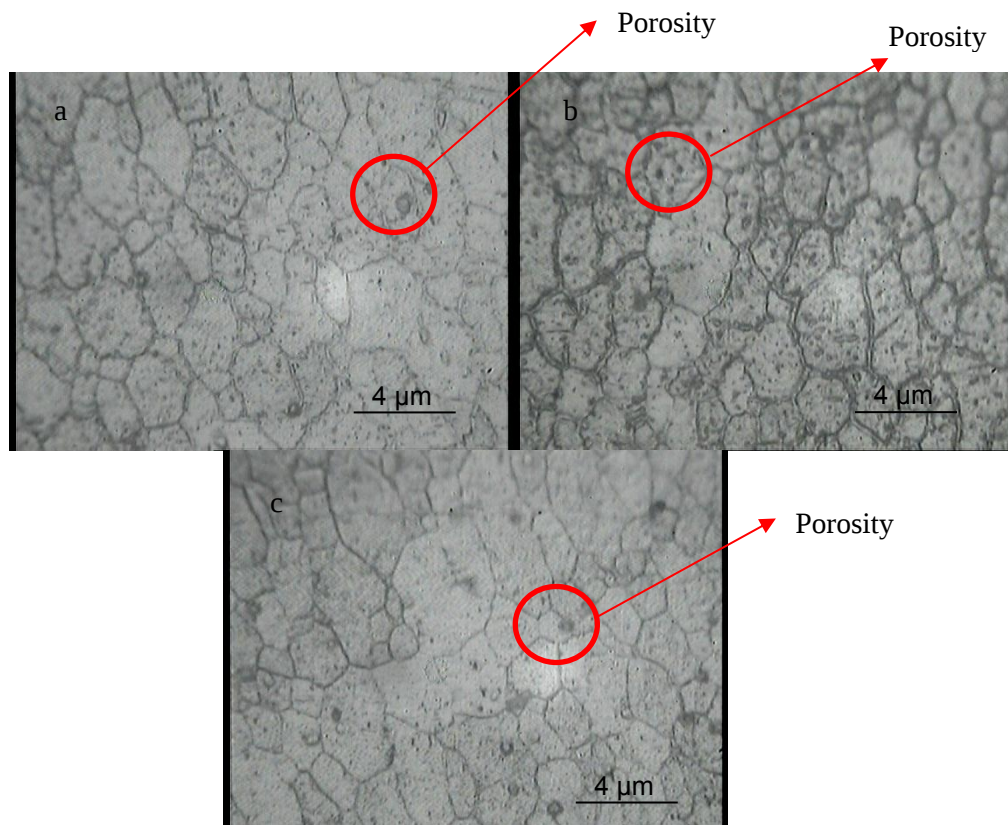


Figure 6. The AWP microstructure has similar grain size and porosity defects; a) 47 g, b) 48 g, and c) 49 g

1. It can be seen that the results of the AWP casting microstructure have the same grain size and evenly distributed porosity. The microstructure results were answered as a result of porosity test with the highest average rate of 43.22%.
2. Gas porosity is caused by the formation of air bubbles in the casting process when cooled. This happens because most liquid metals can store large amounts of dissolved gas, but when in the form of metal alloys can not store a lot of dissolved gas, the gas bubbles will be trapped in the metal found in the casting. Gas porosity can form on the product surface, this porosity can increase the risk of stress corrosion.
3. This casting ingot unwearable for construction materials, so it needs to be re-cast by the die casting method and in combination with other elements such as Mg and Si so the material properties are getting better.

4. Conclusion

Based on the results of this research on the re-casting process on AWP using metal molds and pouring temperature of 700°C in the liquid position can be concluded as follows:

1. Remelting or re-casting causes high porosity with an average porosity percentage value of 43.22% for 43 g cluster, 41.85% for 48 g, and 40.55% for 49 g cluster.
2. Due to the high average porosity percentage, aluminum casting ingots have not been used for construction materials, but can be used for other metal coating processes to inhibit corrosion..

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