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Recycling Metal Waste Made From Aluminum into Ingots: Using the Melting Method with a *Crucible Furnace (Lift Out)*

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Abstract

Aluminum is one of the metal that is widely used for various purposes at this time ranging from use for packaging beverage cans to building construction, automotive, and transportation. Aluminum is widely used because of its toughness, lightweight and rust resistance. The number of uses of aluminum has an effect on the existence of its waste, which will also increase. Aluminum waste processing has been carried out using the melting method into aluminum ingots as raw material for the aluminum industry. Aluminum waste samples come from vehicle and automotive repair shops. A total of 1.5 kg of workshop waste is cut into sizes smaller than 7 cm and then melted separately for 500 grams, each using a crucible furnace (lift-out). The melting is carried out 3 times by varying the amount of flux entered, respectively 0%, 0.2%, and 0.4% w/w. The flux used in this smelting is Na_2CO_3 (Borax). The melting process takes 20-30 minutes, and the temperature of the molten metal pouring is 697-715 °C. The results of the melting of the first 500 grams of waste without using flux resulted in 460.7 grams of ingot and 27.6 grams of melting dross. In melting using a flux of 0.2%, it produces 437.7 grams of ingots and 61.2 grams of dross. In melting using 0.4% flux, the ingot weight was 420.7 grams and dross weight 68.1 grams. The more use of flux in the aluminum waste recycling process using the melting method, giving the effect of weight loss ingot produced, and the increase in weight of dross is wasted. This is because the impurities in the ingot have bonded with the flux and migrated to the waste along with the dross.

Keywords: Aluminum, Waste, Smelting, Flux

1. INTRODUCTION

Waste or garbage, according to the definition of the WHO World Health Organization, is something that is not used, no longer used, and disliked. This waste comes from something disposed of from human activities and does not happen by itself. Based on its nature, waste is classified into three, namely organic waste, inorganic waste, and toxic waste (B3). Based on the type, waste is classified into several types, including food waste, garden waste, paper waste, plastic-rubber-leather waste, cloth waste, wood waste, metal waste, glass-ceramic waste, ash or dust waste (Hadiwiyoto, 1983). The increasing number of waste disposal activities will have an unhealthy impact on the environment. Metal Waste is a type of waste that is difficult to decompose but does not cause odor. Based on its nature, which is difficult to decompose, effective management of metal waste is needed to maintain the sustainability of better environmental quality. One of the easy metal waste management that can be applied to small or medium-sized industries is by smelting metal into waste that has started to accumulate.

Aluminum is one of the most widely used metals in the world today. The use of aluminum, among others, is for the manufacture of aircraft bodies, motor vehicle spare parts, construction, canned beverage packaging, as well as for household furniture. The use of aluminum is favored by many consumers because it is tough, lightweight, and resistant to rust. A large number of uses of aluminum in various lines of life causes the potential for aluminum waste to be disposed of, also increasing. Aluminum has a low melting point, so by taking advantage of the low melting point of aluminum, aluminum waste processing can be done simply. Processing of aluminum waste into ingots is considered to be more efficient because it consumes less energy when compared to processing aluminum, which comes from the ore from the mining process.

In this experiment, aluminum waste smelting was carried out from workshop waste, which had a relatively large amount and was often found in various places. So it is hoped that this waste treatment can reduce the amount of waste that has accumulated in locations affected by waste. The type of metal to be smelted is cut into smaller sizes and then melted separately using a crucible furnace (lift-out) with different variables in the addition of flux. The addition of flux aims to bind impurities so that they can be separated and wasted as dross. The results of smelting in the form of ingots (solid aluminum) are expected to meet the required quality for further purposes.

II. LITERATURE REVIEW

A large number of uses of aluminum in various lines of life causes the potential for aluminum waste to be disposed of as well. Aluminum has properties as a white metal that is not attracted by magnets, non-toxic, easy to melt at a temperature that is not too high, around 660^oC. The processing of aluminum waste into ingots is more efficient because it consumes less energy when compared to processing aluminum from ore (Muller, 2011). The aluminum industry is one of the important basic metal industries besides iron and steel, and its use is also very much needed in national infrastructure (Nurjaman et al., 2019). The national industrial capacity in 2011 was 684 thousand tons per year. This consumption comes from domestic consumption of 287 thousand tons and the rest from imports of 383 thousand tons. (D.J.I.L.M.A.T.D.E.K. Perindustrian, 2015). There is still import dependence on the metal industry. From January to June 2012, imports of raw and auxiliary materials increased by 7.48% in line with increased investment in the manufacturing sector. On the other hand, the use of metals, especially those made from aluminum, has begun to enter its useful life, so a lot of metal waste has started to accumulate in landfills. There needs to be a solution to the problem of dependence on metal imports while reducing the increasing amount of waste; one of the solutions is the metal recycling process. Recycling includes the process of smelting waste and reprinting. Basically, the results obtained in the smelting process do not reduce the quality of the precious metal. Aluminum is one type of metal that is easily recycled, so it requires waste management that is able to support national industrial development (P.K. Perindustrian, 2015).

The use of aluminum in Indonesia is dominated by the automotive industry, which is increasing, as seen from the number of vehicles that are increasingly in demand for transportation and logistics purposes. Along with the great demand for aluminum base metal, on the other hand, metal waste originating from aluminum metal is also increasing, including supporting tools for the home industry (aluminum beverage packaging cans, electronic tools, cooking utensils, automotive, construction, and other metal tools). From these various waste sources, aluminum smelting comes from workshop waste, which has a relatively large amount and is often found in various places. Aluminum waste smelting generally uses a crucible furnace (lift-out) type because it is easy and practical. Crucible furnace or also known as crucible used for smelting non-ferrous metals such as bronze, brass, zinc alloys, and aluminum. Crucible capacity is generally limited to the capacity of small and medium industries. Crucible is the oldest furnace used in metal smelting. This furnace has the simplest construction. This furnace is very flexible and versatile for small and medium-scale smelters. This crucial furnace fuel is gas or fuel oil because it is easy to supervise its operation (Mubarak and Akhyar, 2013). Meanwhile, the lift-out crucible kitchen is a crucible kitchen that is a crucible, and the smelting kitchen is separate so that when the metal has melted, the crucible is removed from the kitchen and used as a pouring ladle (Mubarak and Akhyar, 2013). After the process of smelting the waste, it is then reprinted. In general, people are familiar with the melting process with the term casting, which is a process of melting or forming metal which is poured into a mold, then allowed to cool and freeze. The casting process includes mold making, metal preparation, and smelting, pouring molten metal into molds, cleaning ingot products, and recycling mold sand. The sand molds that are used today are being replaced by metal, which is easier and more practical. The results of smelting aluminum waste are in the form of ingots and dross. The resulting ingot will be forwarded to the downstream industry for further processing, while dross becomes a waste product. Dross is a solid floating on molten metal; dross consists of impurities such as paint residue in the initial melting feed. This dross can easily be separated before metal molding because it floats on top of the molten metal.

In accordance with Law No.18 of 2008 concerning waste management and Law No.23 of 1997 concerning Environmental Management, this experiment is expected to provide a solution to a large amount of aluminum metal waste. This research activity also contributes to the development of science and technology in the field of metal waste treatment.

III. RESEARCH METHODOLOGY

III.1. Materials

The aluminum waste used in this experiment is waste collected from workshop waste and automotive components (motor vehicle spare parts) made of aluminum, including pistons, engine blocks, cylinder heads, valves, wheels, and defective, used vehicle license plates that are broken. The crucible furnace used is modified using a refractory made from CaO (white cement) and using a crucible made of galvanized steel. The flux used in this experiment is Na_2CO_3 (borax) to bind the impurities. The experimental material is shown in Figure 1.

Figure 1.
The aluminum metal waste from workshop waste and automotive components (a);
Na_2CO_3 flux (b);
Modified lift-out crucibles use refractories made of CaO main ingredient (c);
Galvanized steel casting ladle (d).

III.2. Preparation and melting

The aluminum waste from the workshop and automotive is reduced in size to a size smaller than 7 cm. Then, the aluminum waste is put into crucibles and starts to be melted in the kitchen. After the aluminum waste melts, borax is added as a flux to bind the impurities. The impurities that are attached to the floating flux are then removed and removed as dross. The liquid metal that has been separated from the dross is then poured into a metal mold. Experiments were carried out using different levels of borax. The weight of aluminum waste tested in each testing is 500 grams. The flux content used was varied 0%, 0.2%, 0.4% of the initial waste weight.

The process of smelting / liquefying aluminum waste material is carried out in a crucible with a heating temperature of ± 700ºC where the melting point of aluminum is 660 ºC; the heating process is carried out using LNG (Liquid Natural Gas) fuel—melting time for 20-30 minutes for a complete combustion process. The burner is equipped with a hose and a regulator.

IV. FINDING AND DISCUSSION

IV. 1. Effect of Flux on Weight Gain of Aluminum and Dross Ingots

The process of adding borax as a flux to the aluminum waste smelting process makes aluminum ingot recovery less. The more flux is added, the smaller the yield of the aluminum ingot is calculated in the weight. It can be seen in Figure 2 that the reduction in the result of aluminum ingots is quite constant, namely when smelting without using flux and smelting using 0.2% flux, there is a decrease of 23 grams of aluminum ingot weight or 4.9% by weight, whereas from smelting using 0.4% flux has obtained a reduction of 40.2 grams of aluminum weight or 8.7% by weight.

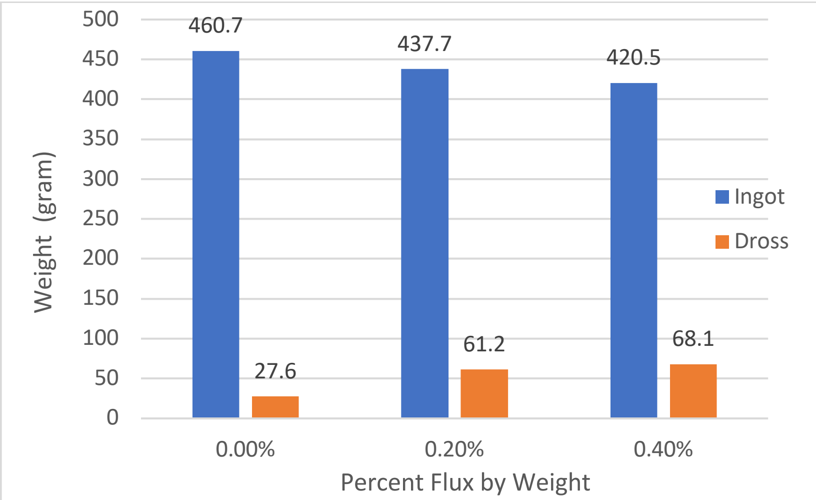

Figure 2.
Effect of adding flux on the recovery weight of aluminum.

The decline in the yield of aluminum ingots as the number of flux increases is inversely proportional to the gain of dross in aluminum waste smelting; it can be seen in Figure 2 that by increasing the percent flux in aluminum waste smelting, the dross gain also increases. A significant increase occurred in smelting without using flux compared to melting using 0.2% flux, which is an increase in dross weight by 33.6 grams or an increase of 121.7% from the result of dross in a melting without using flux. Whereas in smelting using 0.4% flux, it was seen that the result of dross was quite large by 40.5 grams or an increase of 146.7% from the result of dross in smelting without using flux.

IV.2. Effect of Flux on Melting Temperature of Aluminum Waste

The addition of flux (Na_2CO_3) in the smelting of aluminum waste does not have a significant effect on the melting temperature of aluminum because it seems that the starting temperature of aluminum melting is almost constant. Aluminum is indicated as a white metal, malleable, but tough; the powder produces a gray color and will melt at 695^{o}C (Afifah Rosyidah, 2015). Aluminum at a temperature of 695^{o}C is the melting temperature of the whole aluminum, while based on the data in Figure 3, the initial temperature of aluminum melting is around 632-640^{o}C. Here the aluminum still has a phase like sludge that has not completely melted. From the results of the recapitulation of the temperature starting to melt, then the smelting of aluminum waste using the Krusibel furnace (lift-out) can be done with an average temperature of 636°C.

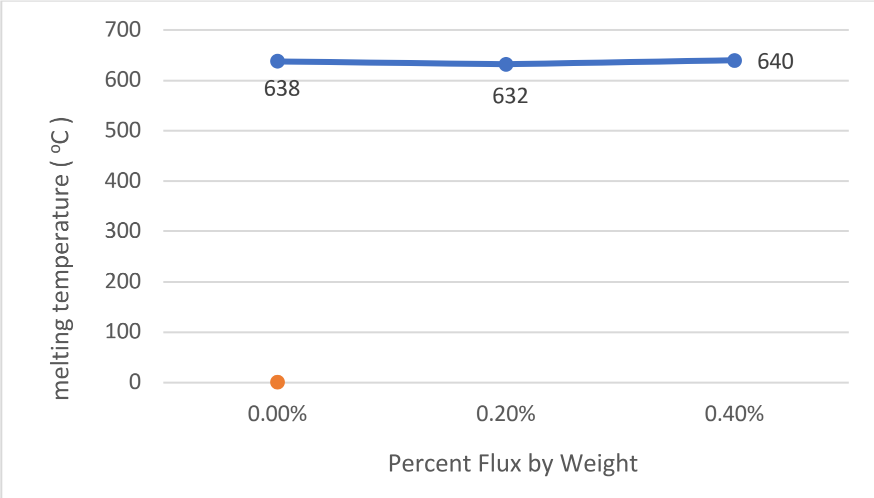

Figure 3.
Effect of adding flux (Na_2CO_3) on Melting Temperature of Aluminum Waste

IV.3.Effect of Flux on Physical Defects of Aluminum Ingot Results

After the aluminum metal waste is melted, the next step is the process of molding or pouring the results of the melting onto a metal mold (Figure 4.a). Visually checking the physical shape of the aluminum ingots (Figure 4.b) resulted in different colors and density levels. In the results of aluminum ingots with the addition of 0.4% flux, the surface pore cavity on the ingot was the smallest (the smoothest), followed by the addition of 0.2% flux, and the process without the addition of flux showed many physical defects, characterized by a large and rough pore surface (Figure 5.a). The results of the physical defects of aluminum ingots without the addition of flux (Figure 5.a), variations in the addition of 0.2% flux (Figure 5.b), and variations in the addition of 0.4% flux (Figure 5.c) it is clear that the addition of flux provides a reduction effect of physical defects.

(a) (b)

Figure 4.
Pouring the results of smelting aluminum waste into metal molds (a);
The results of aluminum ingots with the addition of flux variations are 0%, 0.2%, 0.4% (b)

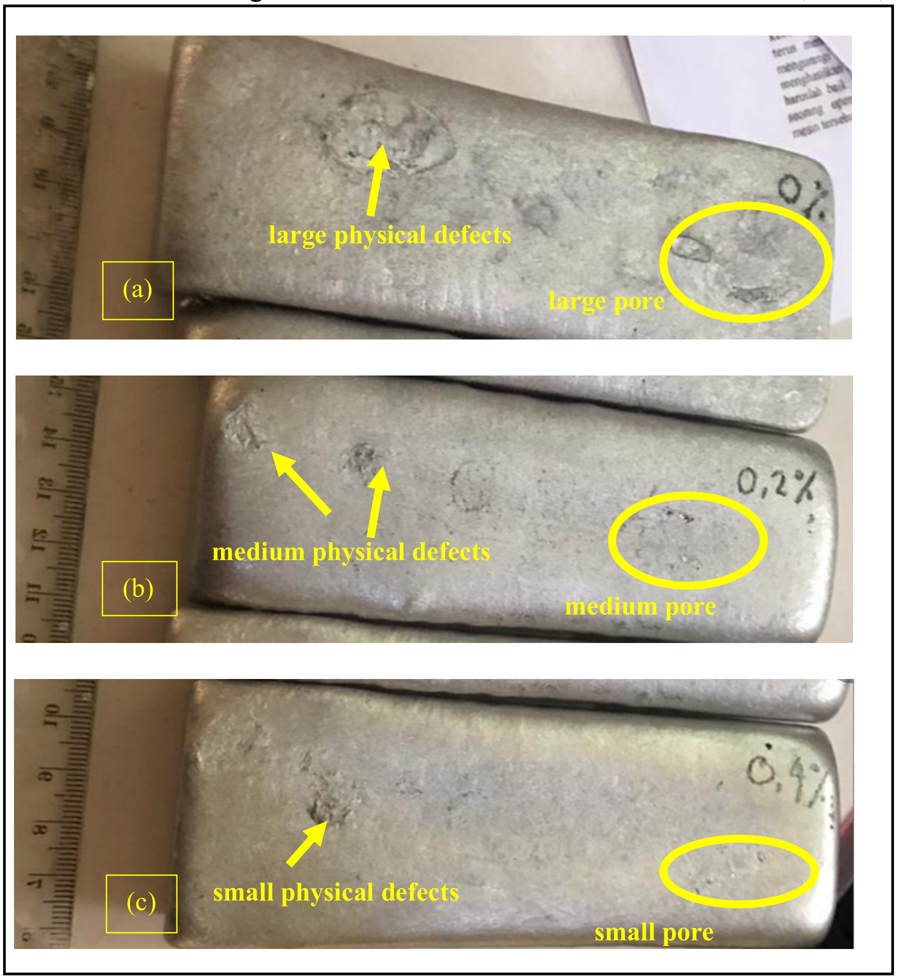

Figure 5.
The results of the physical defects of aluminum ingots without the addition of flux (a)
The results of physical defects of aluminum ingots with a variation of the addition of flux 0.2% (b)
The results of physical defects of aluminum ingots with a variation of the addition of flux 0.4% (c)

The physical results (Figure 5) show that in the smelting process, without the addition of flux, there are still many impurities that have not been separated from the aluminum ingots. In addition, the presence of hydrogen gas during melting, which can dissolve in molten aluminum, also causes porosity in the smelting product. Additives (flux), in addition to binding impurities, can also increase the strength and ductility of the mechanical properties of a material. The presence of several impurities can reduce the mechanical properties of a material; therefore, increasing the amount of flux to bind impurities is very important in the aluminum waste smelting process; besides that, it can prevent oxidation and absorption of gases in the melted product.

V. CONCLUSION AND FURTHER RESEARCH

The conclusions of this experiment are:

a) The existence of aluminum waste, which is increasing, can be reused by smelting to obtain a product in the form of aluminum ingots that can be used as raw material for the downstream industry, which is made from aluminum.
b) The aluminum recycling process starts from the stage of collecting scrap metal, separating, reducing the size, smelting with the addition of flux, molding, and mold control so that the ingots are obtained according to consumer desires.
c) Smelting aluminum waste using the Krusibel furnace (lift-out) can be done with an average starting temperature of 636°C.
d) Sodium Carbonate (Na_2CO_3), or what is known as borax, which is used as a flux in aluminum waste smelting, affects the aluminum ingot recovery and increases the yield of aluminum dross so that the impurities existing during the smelting process can be separated from the main metal.
e) Sodium Carbonate (Na_2CO_3) in smelting aluminum waste does not affect the melting point, so that the presence of sodium carbonate is only as an additive in the smelting process.

For further research, it is suggested:

- Carry out further experiments for other variables in the form of other types of aluminum waste.
- Need a further analysis of the time-variable melting process.
- Perform aluminum ingot characterization tests to see the quality of the desired results, including metallography, microstructure, and mechanical properties of a material (ductility and strength of materials) compared to SNI standard ingots suitable for further processing.

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