

Removal of Oxide Inclusions in Aluminium Scrap Casting Process with Sodium based Fluxes

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Abstract. The investigation of Oxide Inclusions removal in aluminium scrap casting process with sodium based fluxes has been carried out. The purpose of this research is to investigate the effect of Na₂SO₄ and NaCl based fluxes addition onto the fluidity and microstructure of aluminium product. The alloy which is used in this investigation is Al-Si which mixed with metal scrap using gravity casting method. The variation of melting temperature in this investigation are 700°C, 740°C, and 780°C. In this research, material characterization was determined using DSC, EDAX, XRD, and fluidity test. The results show that the number of oxide inclusions decrease as the addition of 0,2% wt. flux, and completely removed after the addition of 0,4% wt. flux. The highest fluidity and tensile strength was obtained after the addition of 0,4% wt. flux. at 740°C..

1 Introduction

Aluminium alloys is widely applied in many industrial product, such as transportation, packaging, construction, or houseware product due to its excellent properties, such as light weight, high corrosion resistance, high castability, and good conductor [1]-[4]. Recently, secondary aluminium is widely used in transportation, building, and packaging industries. Secondary aluminium is an aluminium which is produced by aluminium recycling process using aluminium scrap as its main source [5]-[6]. The utilization of aluminium scrap in the aluminium recycling process has a disadvantage as it contains many impurities element that is not desired in metal casting [7]-[9]. These impurities are considered as unwanted inclusions can reduce the quality of the final product. In metal casting process, inclusion can cause the presence of defect which can reduce the quality of the final product [10]-[12].

Oxides are the most general inclusions which can be formed in metal casting process. Without proper refining treatments of molten aluminum, oxide inclusions will be retained in the aluminum ingots after casting, and invariably causes many problems such as a diminishing of mechanical properties, poor machinability and surface quality [9].

In order to reduce the presence of defect on the final product, it is important to use molten aluminium which free from any impurities in the casting process [13]-[14]. Lately, the most widely accepted and frequently adopted method to remove inclusions such as oxide films from molten aluminum is solid flux refining (also known as refining agents, treatment agents or fused agents).

Chemical components that are used in a flux depends on the objective of casting process (alkali removal, cleanliness, dross separation) [15]. In this paper flux based Na₂SO₄ and NaCl was used to reduce the percentage of oxide inclusions inside the molten aluminium by binding the inclusions into the melt surface.

2 Experimental Methods

Table 1. Chemical compositions of casting aluminium

	Al	Si	Fe	Cu	Mg	Zn
<i>Without flux</i>	89.7	6.1	0.4	2.49	0.39	0.44
<i>With flux</i>	89.4	7.56	0.3	2.03	0.13	0.27

The chemical compositions of casting aluminium are shown in Table 1. According to the result, either the chemical compositions of casting aluminium without fluxing treatment or with with fluxing treatment is AC4B according to JIS standard.

In this research, 20 kg of aluminium scraps were used for each experiment. These aluminium scraps were re-melted in electrical crucible furnace to obtained molten aluminium. Next, the molten aluminium was treated with flux to determine the effects of flux on quality of the final product. Fluxing treatment were performed at various melting temperatures such as 700 OC, 740 OC, and 780 OC, under constant stirring condition for 20

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minutes. In this research, fluxing treatment were performed using saltbase flux about 0.2% and 0.4% weight of of the total molten aluminium. The details of experimental condition for this research are given in Table 2.

Table 2. Experimental Condition

Sample	Material (kg)	Flux	Temperature (C)
1	20 kg	Without flux	700 ⁰ C
2	20 kg	0.2 % wt	700 ⁰ C
3	20 kg	0.4 % wt	700 ⁰ C
4	20 kg	without flux	740 ⁰ C
5	20 kg	0.2 % wt	740 ⁰ C
6	20 kg	0.4 % wt	740 ⁰ C
7	20 kg	Without flux	780 ⁰ C
8	20 kg	0.2 % wt	780 ⁰ C
9	20 kg	0.4 % wt	780 ⁰ C

Fig 1 shows the mould design. In this research, the mould metal which we used is SKD 61 type with gravity casting system for pouring. The products are tensile test specimens which furthermore being through machining process as final step.

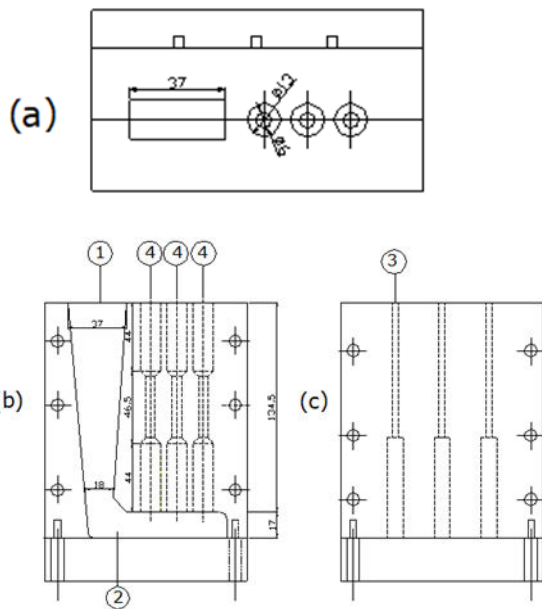


Fig 1. Schematic of casting design. a. Top view. b. Front view. c. Back side view. 1. Downsprue. 2. Runner. 3. Gas tunner. 4. Spesimen [16].

Based on Fig 2, it is shown that the flux based Na_2SO_4 and NaCl has several peaks below 300°C. Those peaks represent a reaction between organic compound and air. At higher temperature, another peak appeared at 696.81 °C, which is higher than the melting temperature of aluminium alloys, which is around 660°C. This high melting point of flux was needed to ensure that the flux

will not melted prematurely and also to prevent high temperature oxidation.

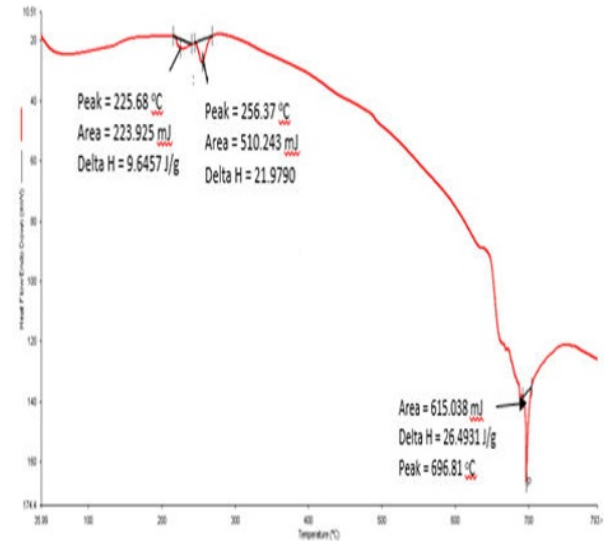


Fig 2. Graphics of DSC flux

3 Result and Discussion

3.1. Microstructural Observation and Phase Identification of Aluminium

Fig 3 shows the microstructure of Al-Si-Cu at various temperature and fluxing conditions. The dark area in samples shows the oxide inclusion in aluminium. Without the utilization of flux, the number of oxide inclusions were high. Otherwise, the number of oxide inclusions were reduced as the melting temperature increased and when the flux was used on molten aluminium. Microstructure in picture B, E, and H show the reduction of oxide inclusions using 0.2% wt. flux. Microstructure in picture C, F, and I show the final amount of oxide inclusions, which is already highly removed using 0,4% wt flux. Flux 0,4 %wt. are the best conditions to reduce the oxide inclusions which formed in aluminium casting process

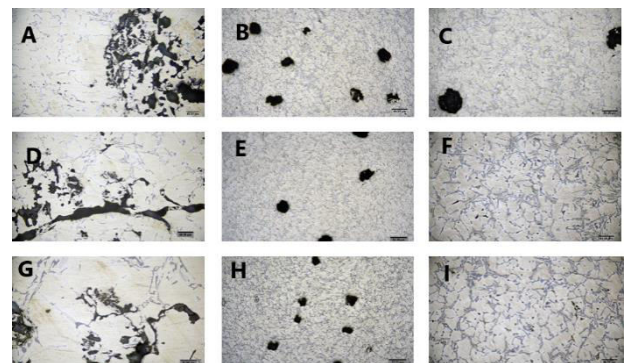


Fig. 3. Microstructure of aluminium casting. A. No flux with temp 7000C. B. Flux 0,2% wt with temp 7400C. C. Flux 0,4% wt with temp7800C. D. No flux with temp 7000C. E. Flux 0,2% wt with temp 7400C. F. Flux 0,4% wt with temp 7800C. G. No flux with temp 7000C. H Flux 0,2% wt with temp 740⁰ C. I. Flux 0,4% wt with temp 780⁰ C

Fig. 4 shows the SEM image of Al-Si-Cu metal which was not treated with flux. The presence of oxide inclusions as shown by number 1, 2, and 3 can be seen in Fig 4. Oxide inclusions can cause porosity inside the sample, it is shown as the dark area beside the oxide inclusions on the image. The prediction of oxide inclusions which appeared in casting process were predicted using EDAX and XRD as shown in Table

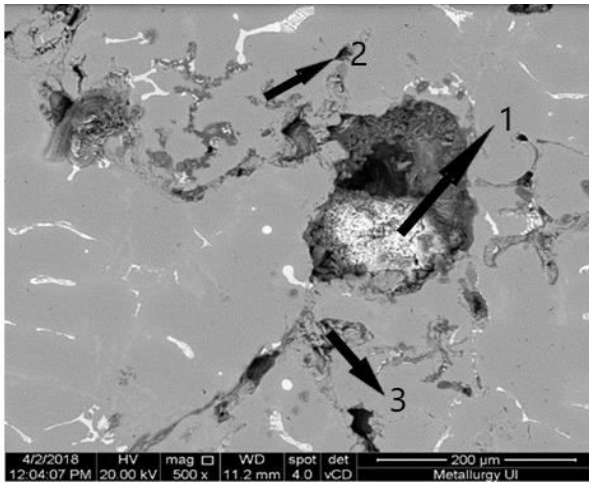


Fig 4. SEM image of aluminium casting without fluxing. 1. MgO. 2. Al₂O₃. 3. MgAl₂O₄

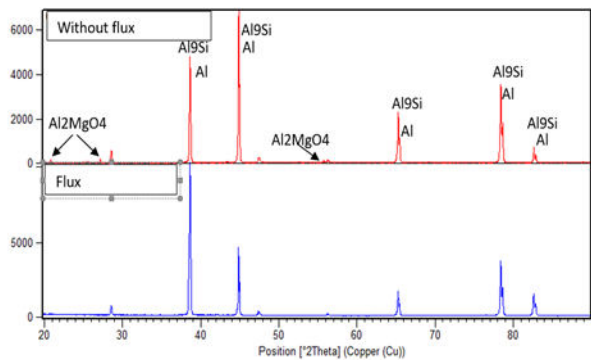


Fig. 5. XRD spectrum aluminum without flux and with flux

XRD patterns of aluminium either with flux or without flux are shown in Fig 5. As seen in Fig 5, the major peak which appeared in sample without flux indicates the presence of Aluminum (Al) and Al₉Si alloy and the minor peak indicates the presence of Al₂MgO₄ and its inclusions. In the other hand, Al₂MgO₄ compounds was not present in sample with flux. The addition of NaF and/or KF in the chloride flux, enhancing the removal of magnesium from aluminum scraps [13].

3.2 Fluidity and Tensile Strength of Casting Aluminium Scrap with Flux

Fig. 6 and 7 show the effect of flux to fluidity and percentage of inclusion in aluminium. In fig. 6, it is shown that the fluidity of molten aluminium increased as the temperature increased. Temperature 7800 C with the addition of 0,4% wt. flux has the highest flow rate with

gradient 0.01. Temperature 7000C with the addition of flux 0,2% wt has gradient 0.009. Otherwise, the molten Al with melting temperature around 700oC but without using flux has the lowest fluidity, with gradient 0.005. The increasing of temperature affects the flux, as the viscosity of the flux reduced. Based on Green and Borne kinetic equation, molten salt viscosity (μ) is related to the root of inverse absolute temperature

$$\mu \propto (1/T)^{1/2} \quad (1)$$

Table 3. Result of EDAX casting aluminium without fluxing treatment.

No	O	Na	Mg	Al	Predicted Inclusion
1	39.24 %	03.66 %	16.29%	30.26%	MgO
2	38.97 %	07.80 %	26%	26.73%	Al ₂ O ₃
3	46.55 %	02.20 %	25.99%	26.73%	MgAl ₂ O ₄

From equation (1), we can see that viscosity and temperature has an inverse correlation. The viscosity of flux decreased as the melting temperature increased, thus the fluidity of flux inside the melt increased. Furthermore, the diameter of flux particles also decreased and the filtration efficiency of flux was improved. As the contact area between the flux and molten metal increase, the probability of contact between oxide inclusions with flux increased and wetting phenomenon happened [7]-[12]. Temperature also have an optimum point, after the optimum point is passed, the filtration efficiency of flux particles inside the molten metal reduced.

Fig 6. Effect of Flux Addition on Fluidity. a. Treatment flux at temp. 700⁰C. b. Treatment flux at temp. 740⁰ C. c. Fluidities is a liquid metal flow ability at melting temperature before stopping due to solidification. The effect of inclusions on the fluidity is The fluidity of pure aluminium is significantly reduced by the presence of oxide inclusion because oxide inclusion barrier liquid metal flow. Fluiditas of samples are Increasing temperature with addition of flux. Because Adding flux and temperature in aluminum casting can reduce inclusion so that it increases metal fluidity.

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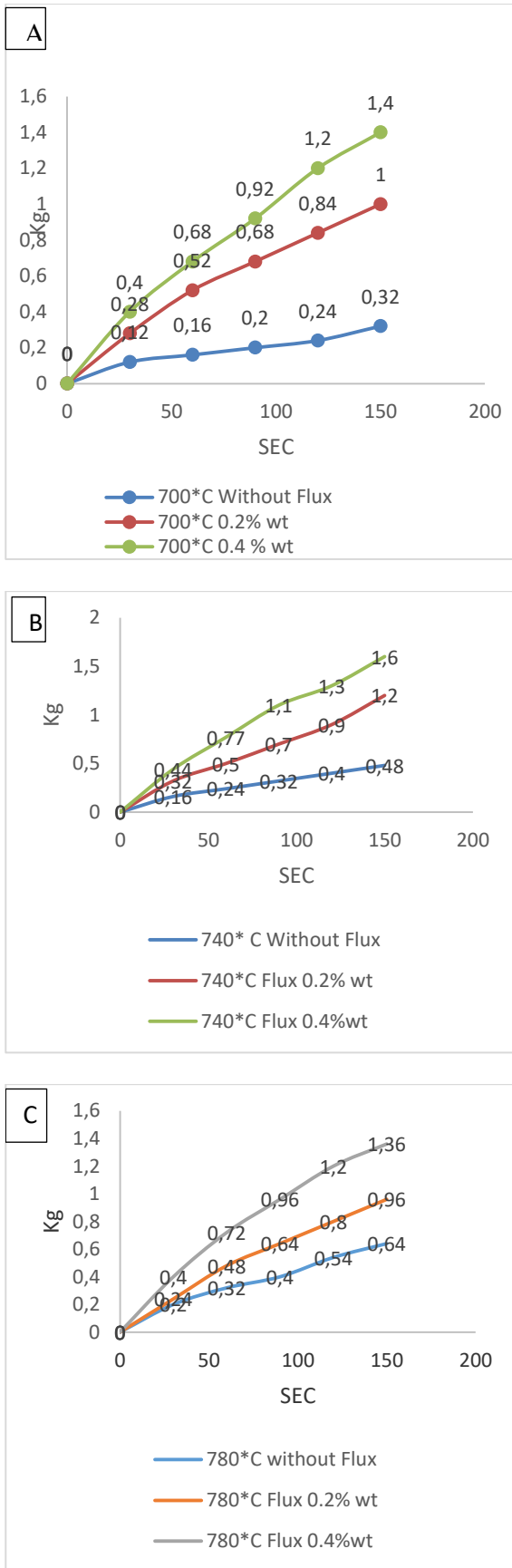


Fig 6. Effect of Flux Addition on Fluidity. a. Treatment flux at temp. 700°C. b. Treatment flux at temp. 740°C. c. Treatment flux at temp. 780°C

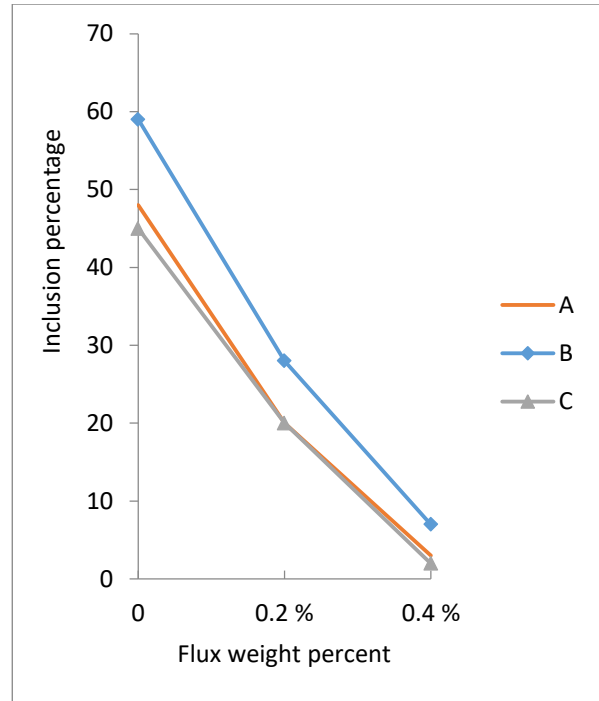


Fig 7. The effect of Flux Addition on Inclusion Percentage. A. Temperature 740°C. B. Temperature 700°C. C. Temperature 780°C

In fig. 7, the amount of inclusions percentage was reduced as the number of flux weight percentage increased. The floatability of inclusion in molten metal is affected by the wettability of inclusion and oxides with the molten metal and molten flux. By increasing the amount of flux which used in casting, the contact surface for inclusion to be wetted by flux will be increased. As a result, the increasing weight percent of flux will increase the filtration efficiency and thus increases the rate of deletion of inclusion via flotation by gas bubbles [7].

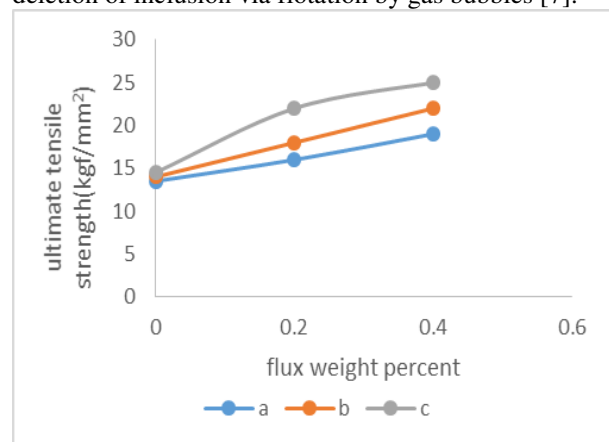


Fig 8. Effect of Flux Addition on tensile strength. A. Temperature 700°C. B. Temperature 740°C. C. Temperature 780°C

Fig 8 shows the results of tensile strength of Al-Si-Cu. Based on the graphic, ultimate tensile strength (UTS) of samples are increased with the addition of flux. The presence of oxide inclusions inside the molten aluminium reduce the tensile strength of the samples, as it can be a local tension concentration area that form the crack initiation. The presence of porosity around the

oxide inclusions also affect the strength of the samples, as the porosity will become a large hole that will help fracture inside samples to propagate [7].

The addition of flux on Al-Si-Cu metal will reduce the number of oxide inclusions. Flux particles will penetrate inside the molten aluminium and thus bind the oxide inclusions through wetting process. The reduction of oxide inclusions affects the tensile strength of Al-Si-Cu, which will improve the quality of final product.

4 Conclusion

The addition of flux based Na_2SO_4 and NaCl improves the quality of molten aluminium in the casting process. This is due to the role of flux that bind the oxide inclusions out of the molten metal into the surface. Oxide inclusions decreased as the weight percentage of flux and the melting temperature increased to its optimum point. Fluxing treatment at 740°C has the highest efficiency on removing oxide inclusions. Fluxing has the best fluidity aluminium molten at temperature 740°C with flux 0.4%. The addition of flux also increases the tensile strength of Al-Si-Cu, and it has higher tensile strength with the addition of more weight percentage of flux.

The authors gratefully acknowledge financial support provided by Hibah PITTA with contract No. 2421/UN2.R3.1/HKP.05.00/2018.

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