The effect of flux’s towards Mg reduction from aluminium beverage cans

A Juniarsih, S Oediyani, and A P Zain
Metallurgical Engineering, Universitas Sultan Ageng Tirtayasa, Cilegon, Indonesia
Email: andinnie@untirta.ac.id

Abstract. Aluminium beverage cans scrap recycling is expected to fulfil aluminium needs in Indonesia, reduce production cost, and pollution generated. Fluxing is one of the methods that can be used to reduce impurities in aluminium alloys such as magnesium, flux also can protect molten metal reacted with oxygen. In this research, aluminium beverage cans scrap used to consist of carbonated, isotonic, and refreshing beverage cans and NaCl+KCl as flux. The holding time of salt fluxing process was 60, 120, 180 and 240 minutes and 5, 10 and 15% variation of flux mass from total scrap mass. Ingot from the recycling process tested to know the percentages of Mg reduction and acquisition of Al using XRF analysis and metallographic. The result showed that the highest percentage of Mg reduction was 77.83% on the addition of the sample of 15% flux for holding time 120 minutes, but Al reached 97.49% for holding time 240 minutes on same flux. On the addition of 10%, flux for holding time 180 minutes was reached 98.82% for yield, 71.84% for recovery, and recycling efficiency 70.53%.

1. Introduction
Aluminium needs in Indonesia in 2016 is in the range of 899.000 tons. Meanwhile, from its supply aspect, the availability of supply in the country is still very limited. One of the single supplier factories of primary aluminium (ingot), with a production of 250.000 tons a year, is only able to supply the domestic needs of 103 thousand tons a year and most of the rest must be exported to Japan because it is tied to a cooperation agreement. Therefore, there is an aluminium supply-demand gap between country’s needs and demand which outstrips supply, so that shortage of demand obtained through imports [1]. With the need which continues to increase and the company's production of primary aluminium is not able to meet those needs, a process to address the needs of the domestic aluminium is needed. A method that can be used is the process of recycling of beverage cans made of aluminium by smelting. Beverage cans that have become waste cannot be degraded by the soil and the danger posed by waste beverage cans is not only have an impact on the ground, but the human beings could be affected from beverage cans. Some of the consequences are cancer of the lungs and liver, caused by flakes of waste beverage cans [2, 3].

Beverage cans’ scrap is the largest source of raw materials for recycling aluminium scrap. Beverage cans’ scrap are easier to be collected than aluminium scrap from another packaging, as can be found both in the residential as well as trash in landfills. Smelting of aluminium scrap is intended to increase the levels of aluminium and one of the ways used is to use salt layer. The expected outcome of the aluminium scrap of refining process is removing impurity metal from aluminium. The process that can be done in smelting aluminium scrap is fluxing. Fluxing process on scrap smelting process will bind impurity metal so that it was separated from aluminium[4].
Fluxing process using salt flux on the aluminium scrap is one of the techniques to remove impurities that exist in aluminium. The Salt compound of the smelting process has several roles, a passive role is to protect the metal from oxidation and active role is to remove impurities from molten aluminium. Flux is often in the form of chlorides and fluoride salt with additives, most of the flux is based on a mixture of NaCl and KCl [5, 6]. The purpose of the research of aluminium beverage cans’ scrap recycling cans is to increase Al’s levels up to 99% and reduce Mg’s levels up to 50%.

2. Experimental Design

2.1. Materials
Aluminium beverage cans’ scrap that was used consisted of three kinds of beverages which are carbonated, isotonic, and refreshing beverage cans. The smelting process used induction furnaces with smelting process temperature is 750°C. In this research, the process of recycling was done to reduce the levels of Mg, used flux salt compound which was KCl-NaCl with the composition of the 50% KCl and 50% NaCl.

2.2. Refining Process
The refining process was done by adding KCl-NaCl flux into the smelting of beverage cans’ scrap to bind the impurity metal. Flux in the smelting was added with variation mass of 5, 10 and 15% of the total scrap mass. Holding time was given to the fluxing process to see the effect of time towards the impurity metal’s reduction and an increase of Al’s acquisition. Holding time given during the fluxing process were 60, 120, 180 and 240 minutes. The result of scrap's smelting was moulded with a length of 2.5 cm, wide of 2.5 cm, and high of 1 cm

2.3. Characterization of Aluminium Beverage Cans’ Scrap Recycling
The composition of scrap remelting could be seen by using X-Ray Fluorescence (XRF) testing with WDXRF Spectrometer model. XRD testing was used to determine Al’s acquisition and Mg’s reduction from beverage cans’ scrap recycling’s result. The Microstructure of remelting could be formed by using a proper etching solution and the results could be seen by using an Optical Microscope.

3. Result and Discussion

3.1. Influence of Fluxing Process’ Holding Time towards Reduction Percentage of Magnesium’s Levels
Figure 1 shows that the addition of flux mass of 5, 10 and 15%, the longer the holding time was used, the more increasing the reduction percentage of the Mg’s levels. However, there is an anomaly in the addition of 15% flux with holding time of 180 minutes. The chemical reaction that occurs will affect a wide range of value on the outcome of the process of melting the aluminium beverage cans’ scrap because the reaction between chemical is capable of effecting on levels of impurity metal’s decreasing and capable of reducing levels of valuable metal.
3. The Influence of Flux Mass and Fluxing’s Holding Time towards Characteristic of the Al’s Acquisition

Figure 2 shows that the longer the holding time of fluxing, more increasing Al’s acquisition. This situation is caused due to the longer time spent in the process of fluxing so that the binding process of flux towards the impurity metal will increase [6, 8, 9]. However, there is an anomaly that occurs in...
Figure 2 the anomaly that formed caused by chemical reaction. The chemical reaction that formed shown in Eq. 1 and Eq. 4. The reaction between the oxide and Al metal can cause a bond to form Al oxide, so that Al will be on the surface of the molten metal and become dross, resulting in decreased levels of valuable metal. Another circumstance that caused anomaly is a different chemical composition between the lid and body of the cans. The standard used for the lid of aluminium beverage cans is AA5182 with Mg composition ranges from 4-5%. For cans’ body, its standard is AA3004 with Mg composition ranges from 0.8 to 1.3% Mg and Mn levels of 1-1.5% [2, 10-16].

The influence of adding flux mass also affects the results of Al’s acquisition from research undertaken. Figure 3 shows the influence of flux mass on Al’s acquisition. Gokhan Ozer, etc (2013) stated that the influence of flux mass was at its maximum in flux addition of 5%, less or more than 5% addition of flux produced yields of Al is smaller than the addition of 5% [9]. From this research, it can be seen the influence of flux mass to Al’s acquisition in Figure 3, for the result of adding flux of 10-15% it increased Al’s acquisition, and it can be associated with the function of fluxing’s holding time which affected flux’s maximum ability to bind impurity metal. This situation came from the amount of flux which was higher so the use of much more flux that can be maximized. It is different from using 60 minutes holding time where the more addition of flux, more decreasing Al’s acquisition. That situation was caused by flux which was not in its maximum ability to bind impurity metal because given time is less.

Characteristic of Al’s acquisition of recycled beverage cans can be seen in the form of the microstructure shown in Figure 4. According to Figure 4 which is about the shape of the microstructure of remelting beverage cans’ scrap, there is a phase difference between the sample of after and before treatment. Based on Figure 4 (a), (b) and (d), it can be seen that the dominant phase formed is the Mg2Si phase. Mg2Si dominant phase held in Al-Mg alloys with Mg composition of 2-5%, the form of Mg2Si phase is like Chinese writing or fishbone shape [12,17,18]. The results of XRF testing which is shown in Table 1 describes that the composition of Mg on Figure 4 (a) and (d) is different for the result of metallographic which shows the microstructure of Figure 4 (a) and (d) that phase that is formed is a Mg2Si dominant phase.

Figure 4 samples (b) the dominant phase which is formed is intermetallic phase Al6 (Fe, Mn) and a little phase of Mg2Si. Al6 phase (Fe, Mn) formed because Mn content is higher than Mg content. This situation is caused by the treatment process conducted with the aim of eliminating the Mg content. Increased levels of Mn produce eutectic fractions intermetallic. That situation happened during freezing occurs very slowly and produced intermetallic Al6 phase (Fe, Mn) as the main phase [18].

![Figure 2](image2.png)

**Figure 2. The Influence of Fluxing’s Holding Time towards Al’s Acquisition**

![Figure 3](image3.png)

**Figure 3. The Influence of Mass Flux on Al’s Acquisition**
Figure 4. Microstructure (a) F15H1 (Minimum), (b) F15H2 (Maximum Reduction of Mg), (c) F15H4 (Maximum Al’s acquisition) and (d) Non-Treatment. 500x magnification

Table 1. Percent Change in the Elements of Recycled Aluminium Beverage Cans’ Scrap

| No  | Sample       | Mg (%) | Al (%) |
|-----|--------------|--------|--------|
| 1   | Non-Treatment 1 | 2.71   | 95.74  |
| 2   | Non-Treatment 2 | 3.49   | 95.11  |
| 3   | Non-Treatment 3 | 3.45   | 95.18  |
| 4   | F5 - H1       | 1.49   | 96.71  |
| 5   | F5 - H2       | 1.97   | 96.25  |
| 6   | F5 - H3       | 1.66   | 96.67  |
| 7   | F5 - H4       | 1.11   | 97.15  |
| 8   | F10 - H1      | 1.72   | 96.51  |
| 9   | F10 - H2      | 1.67   | 96.61  |
| 10  | F10 - H3      | 1.06   | 97.11  |
| 11  | F10 - H4      | 1.18   | 97.13  |
| 12  | F15 - H1      | 2.08   | 96.23  |
| 13  | F15 - H2      | 0.71   | 97.41  |
| 14  | F15 - H3      | 1.52   | 96.81  |
| 15  | F15 - H4      | 0.74   | 97.49  |
a $F = \text{Addition of flux mass (\%)}$

b $H = \text{The given holding time of fluxing (hour)}$

In Figure 4 (c), it also has an Al6 phase (Fe, Mn), but the phase which is more dominant is a Mg2Si phase, this situation was caused due to the build up of Mg levels in some places led to the formation of Mg2Si phase. From the overall pictures of microstructure on each sample, it can be seen that there are so many dendrites formed. Those dendrites appeared as a result of the Coran process. The ingot research’s result formed by casting therefore it is right that dendrites are formed from each of casting’s result [17].

4. Conclusion

Based on the research that has been conducted, it was found that the addition of flux mass and the use of fluxing’s holding time can improve Al’s acquisition and reduce the levels of Mg on aluminium beverage cans’ scrap’s alloy, because the longer the holding time is given, the higher Al’s acquisition and the bigger the reduction of Mg’s levels as well as with the addition of flux mass which is used. The highest percentage of Mg reduction was 77.83% on the addition of the sample of 15% flux for holding time 120 minutes, but Al reached 97.49% for holding time 240 minutes on same flux. On the addition of 10%, flux for holding time 180 minutes was reached 98.82% for yield, 71.84% for recovery, and recycling efficiency 70.53%. Further, can be investigated about the effect of different types of fluxes on Al recovery and reduction of impurities also the addition of the stirring process during initial melting of the sample or during the fluxing process, to determine the effect of stirring on Al acquisition and Mg reduction.

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References

[1] Qomarsono and Hilman 2014 Prospek PT Inalum Pasca Pengambilalihan oleh Pemerintah
[2] Material Safety Data Sheet 2011 2. Used Beverage Container Scrap, Version 1. Tri-Arrow Aluminium Inc
[3] Boin U M J and Bertram M 2005 Melting Standardized Aluminium Scrap: A Mass Balance Model for Europe European Aluminium Association and Organisation of European Aluminium Refiners and Remelters. Brussels, Belgium
[4] Gilstad G 2013 Life Cycle Assessment of Secondary Aluminium Refining Norwegian University of Science and Technology
[5] Tsunekawa M, Yoo K, Hiroyoshi N, and Ito M 2005 Resources Processing 52 32-38
[6] Utigard TA 2001 Properties of Fluxes Used in Molten Aluminium Processing University of Toronto, Ontario, Canada
[7] Estéfano A V 2012 Use of Chlorine to Remove Magnesium from Molten Aluminium Department of Metallurgical and Materials Engineering Brazil
[8] Lifeng Z 2011 Removal of Impurity Element from Molten Aluminium: A Review Department of Science and Technology. Rolla, Missouri, USA
[9] Michael B 2015 Fused Refining Fluxes and Their Reaction Kinetics. Aluminium Smelting Industry MQP ltd
[10] Kiffaya A A and Layla M H B 2008 Recycling of Aluminium Beverage Cans Materials Engineering Dept Al-Mustansiriya University Baghdad, Iraq
[11] George E T and MacKenzie D S 2003 Handbook of Aluminium Vol.1, Physical Metallurgy and Processes Marcel Dekker, Inc. New York – Basel
[12] ASM Metals Handbook 2004 Volume 2 Properties and Selection: Nonferrous Alloys and Special-Purpose Materials
[13] Ron C 1994 TALAT (Training in Aluminium Application Technology) Lecture 1501, Aluminium: Physical Properties, Characteristics and Alloys. Alcan, Banbury
[14] Eric W 1994 TALAT (Training in Aluminium Application Technology) Lecture 3710, Case Study on Can Making Alcan Deutschland GmbH, Göttingen
[15] Gokhan O 2013 The Effects of Proces Parameters on the Recycling Efficiency of Used Aluminium Beverage Cans (UCBs) Istanbul, Turki
[16] Mahmoud A R 2003 Preparation of Aluminium-magnesium Alloys and Some Valuable Salts from Used Beverage Cans Cairo, Mesir
[17] ASM Metals Handbook 2004 Volume 9 Metallography and Microstructures
[18] Yulin L 2016 Effect of Mn and Fe on the Formation of Fe and Mn Rich Intermetallics in Al-5Mg-Mn Alloys Solidified Under Near-Rapid Cooling Shenyang Aerospace University, Shenyang, China