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OXIDATION OF BEVERAGE CANS IN THE TEMPERATURE RANGE 400-610 ^{o}C

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ABSTRACT

Thermogravimetric analyzer (TGA) is a device for carrying out thermal analysis where the mass of the test material will be inversely proportional to or directly proportional to the increased temperature rate and time function. TGA is usually used to determine material characteristics. The increasing mass curve of the element of aluminum material can be used to determine oxidation. The point of rising material mass can be used to calculate activation energy. This study has used a Thermogravimetric analyzer with aluminum test materials from used beverage cans which are melted directly and indirectly with used lubricating fuels. The test results show that the activation energy for direct furnace casting (DF) is 186.2 J/mol and this is greater than indirect furnace casting (IF) which has an E value 92.17 J/mol. Activation energy for CAN cans is 318.8 J/mol, and for used cans without Ink and Varnish Cw/oIV the activation energy is 350 J/mol.

Keywords: aluminum, beverage cans, oxidation, activation energy.

1. INTRODUCTION

It can be said that the increasing population of the world, which affects the amount of aluminium used which also increases. So it can be said that this metal has a big influence on the world economy. The use of aluminum as non-ferrous metals increasingly widespread at this time. As an example of aircraft construction, motor vehicle components, cooking appliances to the food and beverage containers.

Some properties that exist in Aluminum which are lightweight metals are good corrosion resistance, good electrical conductivity, and other good properties as metal properties. When combined with some other metal elements, it will increase its mechanical strength. Said by [1], some elements of alloying are copper (Cu), Magnesium (Mg), silicon (Si), manganese (Mn), zinc (Zn), and nickel (Ni), which individually or together as an element of alloying, also will provide other good properties such as corrosion resistance, wear resistance, and low expansion coefficient.

Along with increasing advances in technology, wastes resulting from the use of aluminum can be recycled. The most commonly used recycling method is the remelting method. In the melting process, metal is heated to above the melting point of the metal followed by a casting process. One of the combustion system for melting aluminum is often used directly, where a flame is directed to an aluminum former which is in the walled furnace refractory cement. In this combustion system, most of the dirt that is attached to the metal surface will burn. In addition, some chemicals have been burned, thereby increasing the purity metals [2].

Solidification of aluminum metal is a process of freezing liquid material into solids and in this case is called the composition process. Some energy is needed for the process. On the other hand, oxidation is a process of adding mass or thin layers by, among other things, giving some oxygen to the material. The addition of these elements is called as an oxidation process using a number of activation energy. In other words that the activation energy is the energy needed to add an element of a metal mass that forms a thin layer.

1.1. Aluminum properties

In nature, aluminum is not formed as the metal because of the chemical bonding of oxygen. Aluminum compounds, especially oxides in various forms of purity and hydration are widespread in nature. In this form, aluminum is the second largest metal element on earth after silicon which is 27.5%. It is estimated that about 8% of the earth's crust is composed of aluminium [3].

1.2 Beverage cans material

Aluminum metal, for beverage cans consists of mostly aluminum, but also consists of several other types of metals. Other metals include magnesium, manganese, steel, silicon and copper. Lid cans made of alloys are slightly different from the base and sides of the can, beverage cans are made of two aluminum alloys, ASTM 3004 for canned parts and ASTM 5182 for canned lid parts, which have different compositions [4]. As according to Surdia T and Saito, Al-Mn Alloys in the AA standard naming are Al 3003 and Al 3004 alloys. [1].

Some aluminum scrap and its impurity elements are, among others, the physical impurity elements, Fe, Zn, Cu and organic material, on the Engine block the impurity elements are Fe, Sn and Sb, while the beverage cans are Fe, Cu, Mg, ink, varnish. [3].

According to research[4]is the developed countries should contribute to protecting the environment by using all recycled materials to save money, energy and raw materials.

1.3 Thermogravimetric analyzer, thermal decomposition and oxidation

Thermogravimetric Analyzer (TGA) is an analytical technique to determine the thermal stability of a material and component fraction by calculating the weight changes associated with changes in temperature. This method provides good results when used to analyze quantitatively, the presence of certain reactions occur during changes in heat temperature and a significantly greater variation in mass changes [5].

The decomposition reaction is a kind of chemical reaction in which a single compound breaks down into two or more elements or new compounds. Thermal decomposition is a decomposition reaction involving energy sources such as heat. (Smeltzer, 1956).Corrosion does not only occur due to the cause of liquid electrolytes which react to metals, but also oxidation can occur in metals and their alloys which react with the surrounding air which forms external oxidation which occurs at high temperatures. The oxidation layer is formed by an electrochemical process where it is not easy to combine metals and oxygen [6].

To determine the magnitude of the activation energy required for heating the material, using TGA, there is a relationship between the reduced periods of aluminum due to rising temperatures. If mass increase is a function of temperature at a constant heating rate with a heating rate as a parameter, it can be assumed that the rate of instantaneous mass change, a reflection of weight loss, is a function of the undecomposed material fraction [7]. In 1889 Arrhenius proposed an empirical equation that provides the basic value of the relationship between the activation energy and the rate of the reaction process. The Arrhenius equation describes the effect of temperature on the reaction rate constant [8].

$K \quad = A^{-E/RT}$
$A \quad$ = frequency factor or Arrhenius factor
$E \quad$ = activation energy (J/mol)
$R \quad$ = gas constant (8,314 J/mol^{o}K)
$T \quad$ = Absolute temperature (^{o}K)
Or:
$\ln k \quad = \ln A - E/RT$

Oxidation study [9]shows the reaction of aluminum with oxygen which has been studied in the temperature range 400 - 600^{o}C and the results of the study explain the presence of initial oxidation levels followed by the growth of thin layers.While research on the aluminum oxidation occurs at a temperature of 200-550 ° C [6].The results of his research showed a mass thinning and gray to black discoloration, which explained the evaporation of mass oxidation.The mechanism and kinetics of the growth of the aluminum oxide layer with thermal oxidation are described by [10]. Oxidation at high temperatures for magnesium aluminum alloy investigated by[11], the material used beverage cans are the raw material that is AA 5182 (lid) and AA 3004 (body).

The influence of other elements on the aluminum of the analyzed thermogvimetri has been investigated by [12], a special curve is formed for a mixture of aluminum and polypropylene. Measured oxidation at temperatures of 500-550 ^{o}C.

The formation of a thin layer that can be called phase 1 oxidation occurs from a temperature of 300 – 600 ^{o}C, as studied by [13].

2. METHODS AND MATERIALS

TGA measures the amount and rate of mass change in a material either as a function of increasing temperature, or isothermally as a function of time, in atmospheric pressure, can be used to characterize any material that shows weight changes and to detect phase changes due to decomposition and oxidation. Tools used Thermogravimetry Analyzer TGA Q500. The atmospheric air used is 99% purity oxygen, with a maximum temperature of 900 °C and a constant heating rate (Ramp) of 10 °C/minute.

There are four types of materials used in this study. But the basic ingredients are the same, namely beverage cans. The first material is beverage cans (CAN), secondly CAN without ink varnish (Cw/oIV), thirdly from the melting of beverage cans, which are melted directly where the combustion flame touches the material surface directly (direct furnace-DF), the fuel is used lubricating oil, and the fourth remelting beverage cans are melted indirectly (indirect furnace-IF).

Material preparation includes collecting aluminium materials to be tested, namely aluminium casts using direct smelting of used oil fuel, aluminium cast using indirect smelting used lubricant. Preparation of test material for the results of melting aluminum is done by means of being crushed into a ready-to-test specimen. To avoid entrainment of elemental iron of the tool miserly and pestle, then was pinned magnetic iron so that iron can be attached. Whereas for beverage cans are finely cut using scissors.

3. RESULTS AND DISCUSSIONS

After a series of preparation steps are carried out, the data obtained from the measurement results are prepared and then processed to take into account the activation energy in the oxidation phase in the aluminum material. Furthermore, the data calculation results compiled in table form and further processed which will then be displayed in graphical form. Measurement results with TGA produce a graph of the relationship between Weight (%), time (minute) and Temperature (^{o}C) Figure-1.

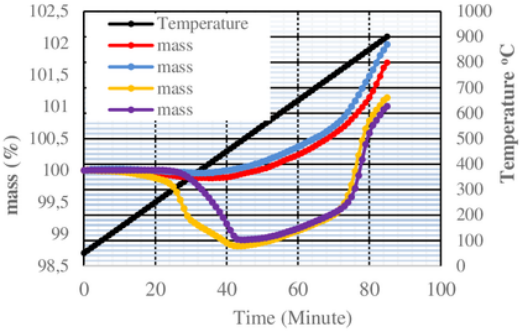

Figure-1. Relationship between mass, temperature and time.

To analyze the peak temperature is made a picture of the relationship between dm/dt which is a change in mass to time (Figure-2).

Four types of samples used in this study have different characteristics. Avoid errors in calculations, then selected the production of beverage cans Cocacola Company, which is a mix of brands of drinks fanta, coke and sprite.

From Figure-1, it can be seen that the mass at the start of the heating experienced a reduction in mass, this is in accordance with that expressed by (Zhorin, Kiselev and Roldugin, 2013). Chart patterns of four different types of these samples and classified in two graphic patterns. CAN and Cw/oIV has a similar chart pattern, while the DF and IF have a similar pattern of both. The fourth type of sample experienced a reduction in mass, especially samples CAN experiencing a very large mass reduction compared to Cw/oIV.

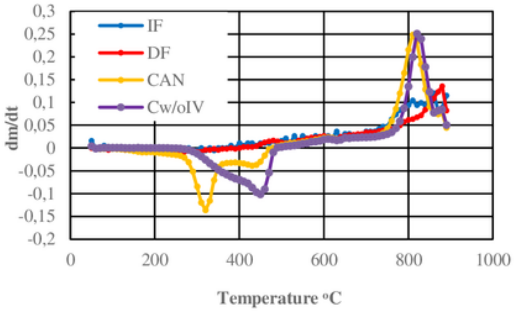

Figure-2. The rate of decrease in mass of the time.

On the CAN sample the mass decreases to 1.1%, this lasts to a temperature of 320 °C for 27 minutes and ends at a temperature of 470 °C in 42 minutes. There are two peaks of this sample in Figure-2. The first peak, estimated varnish, part the outermost layer of cans that burns out, then the ink burns at a temperature of 470 °C. Thus, for samples CAN, begins the oxidation process at temperatures of 470 °C.

For samples Cw/oIV, the reduced mass of this early warming by almost 1% (see Figure-1). The peak temperature of mass reduction occurs at temperatures of 450 °C (see Figure-2) or at minute 40. The end of mass reduction occurs at temperatures of 490 °C or in minute 44 (see Figure-1). The oxidation process starts at 490 °C.

In the DF sample there is a mass reduction of 0.12%, it is estimated that this mass is the residual combustion of used lubricating oil from the direct combustion to the aluminum surface at the time of smelting, and also the presence of moisture from free air attached to the sample surface. The mass reduction ended at 430 °C in the 35th minute. (See Figures 1 and 2).

In the IF sample, the reduced mass is 0.04178%. This small percentage shows that there are no indirect impurities in aluminum material resulting from this fusion, other than Estimates of the presence of moisture from the air attached to the surface of the IF sample. This process takes place at 30 minutes at 349°C and ends at 33 minutes at 379 °C.

The oxidation process for IF samples occurs at temperatures of 400 °C to 610 °C, while the DF sample occurs at a temperature range of 500-600 °C. This exceeds the temperature range disclosed by [13], i.e. oxidation phase I occurs at temperatures of about 300 – 600 °C.

From Figure-2 it can be seen that the curve line for the CAN sample starts to rise at a constant temperature of 490 °C to temperatures around 610 °C and Cw/oIV starts at a constant temperature of 490 °C to reach a temperature of around 610 °C.

Comparing studies [13] with the measurement results it can be said that the measurement range is close to phase I. So that the amount of energy activation in the oxidation process for each sample can be calculated. Calculation of the amount of activation energy starts from the temperature when the mass reduction process has stopped. Where at that time began to increase the mass of oxygen to form a thin layer on the surface of aluminum. The final oxidation temperature is limited to around 600°C.

For four samples used, it can be seen the relationship between ln k and 1/T in Figure-3.

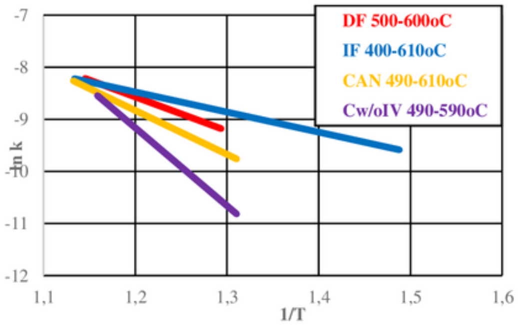

Figure-3. Relationship of Arrhenius between ln k and 1/T.

The amount of activation energy that can be calculated from Figure-3 is the amount of activation energy needed to process the oxidation of aluminum materials. The activation energy of the IF sample is 92.17

J/mol, with the temperature of the oxidation occurring in the range 400 – 610 °C. For the DF sample the activation energy required for the oxidation process is DF 186.2 J/mol, with the temperature of oxidation occurring in the range 500 – 600 °C. The amount of activation energy for the CAN sample is 318.8 J/mol, at the temperature of the oxidation occurrence in the range 490 – 610 °C. While the activation energy of the Cw/oIV sample is 350 J/mol, at the temperature of the oxidation occurrence in the range 490-590 °C.

The start and end of the oxidation temperature is calculated by looking at Figure-2, where the end of the dm/dt reduction process is the beginning of the addition of oxygen mass. While the temperature range used in the calculation is based on the steady increase in dm/dt. The fourth temperature range of the sample is determined based on the maximum value of the coefficient of determination of r^2 of each linear equation formed, where the largest r^2 of each of these is the level of trust that is believed to be the basis of the best linear equation.

A large temperature range from IF indicates the length of time needed for the oxidation process compared to other samples (see Figure-1). But the difference in the large temperature range does not show the greatest activation energy among the samples. Each sample has an activation energy with each different temperature difference (see Figure-4).

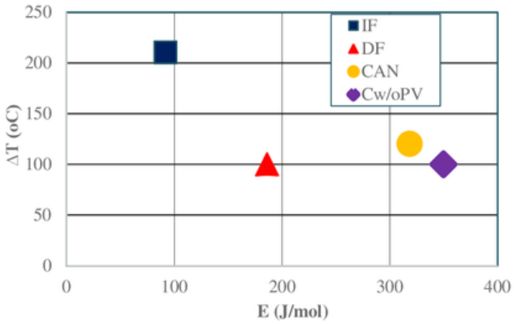

Figure-4. The relationship between the magnitude of the difference in temperature and activation energy.

From Figure-4 it can be seen that the DF sample has a greater activation energy compared to IF. Direct smelting (DF) has shown advantages compared to indirect smelting. The low temperature difference from the DF sample has resulted in a greater activation energy compared to the IF sample. This shows that direct melting, where the combustion flame is directed directly to aluminum material has significantly reduced impurity elements. Likewise, when compared between CAN samples which are samples that still contain ink and varnish, which requires a greater temperature than Cw/oIV which is a can without ink and Varnish.

4. CONCLUSIONS

The four samples in this study have shown the characteristics of each. CAN samples, which still contain ink and varnish require a large temperature difference to do a smaller oxidation process compared to Cw/oIV at a smaller temperature difference. So the Cw/oIV sample needs a lower temperature difference to get large activation energy. The smelted sample with the indirect furnace (IF) method has a greater temperature difference compared to a direct furnace (DF) samples. Where the activation energy of DF is greater than IF. The presence of impurities in the form of combustion of lubricating oil into the melted material by direct combustion shows the advantage for DF to obtain greater activation energy with a lower temperature difference. This shows that direct combustion has added value in the oxidation process of aluminum beverage cans.

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