ENERGY ACTIVATION OF DECOMPOSITION OF CASTINGS OF PURE ALUMINUM - STANNUM ALLOY

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ABSTRACT: Thermogravimetry analyser is a tool to perform thermal analysis where the mass of the test material will be inversely or directly proportional to the increasing temperature rate and a function of time (constantly increasing temperature). The results of the TGA test are a comparison of mass to times, mass to DTA, and the ln k to 1/t; all relations to determine the oxidation point and activation energy required for each sample can be known. The samples used were 4: pure aluminium, pure aluminium mixed with 2% Sn, pure aluminium mixed with 6% Sn, and pure aluminium mixed with 10% Sn. The activation energy required for each sample is as follows, pure Aluminium of 64.24 kJ/mol, pure Aluminium mixed with 2% Sn of 58.70 kJ/mol, pure aluminium combined with 6% Sn of 16.63 kJ/mol and Aluminium pure mixed with 10% Sn at 47.68 kJ/mol.

KEY WORDS: Aluminum, Stannum, Oxidation, TGA, Activation Energy.

1. INTRODUCTION

Aluminum which was initially called aluminum and was later agreed to end in ium [1], many still use the Heroult Hall method [2] in producing it. Aluminum and its alloys possess unique properties: lightweight, corrosion resistance, strong, strong at low temperatures, formability, heat conductor, high reflexivity, electrical conductor, easy surface treatment, non-magnetic, non-toxic, and many other properties [3]. The emergence of industrial 3.0 demands consistent material characteristics; the unique qualities of aluminum and its alloys are favourable for the growth of production and use of new metals [4]. At this time, aluminum is used to meet the needs of the transportation industry, manufacture of beverage cans or other forms of packaging, in the construction sector, in the electrical industry, and other fields [5]. The nature of pure aluminum is fragile and soft, so to increase its strength, it is usually combined with other metals [6]. One way to combine pure aluminum with other metals is to cast it. Casting can produce simple to complex products with varied shapes, ranging from gram to tonne units, as well as minimal finishing processes to save cost and time in the forming process [7]. One of the metal materials that can be used as an alloy is tin (Sn) [8].

Thermogravimetric Analyzer (TGA) is an analytical method used to determine the thermal stability of a material and its fractional components by calculating the change in mass with temperature changes. This method gives good results when used to analyze quantitatively; there is a reaction that occurs when changes in hot temperature and significant variations occur in changes in mass [9]. With the TGA tool, thermal analysis can be carried out where the mass of the test material will be inversely or directly proportional to the increasing temperature rate and a function of time (constant temperature increases). TGA is usually used to determine material characteristics. The curve of the increasing mass of Aluminum material can be used to determine oxidation. The point of increase in the mass of the material can be used to calculate the activation energy [10]. The measurement process with the TGA method is carried out by increasing the temperature of the combustion chamber gradually with room temperature with a constant increase every time until the desired temperature [11] with an oxygen or nitrogen atmosphere. Decomposition is a reaction that breaks down complex chemical compounds into simpler chemical compounds. The decomposition reaction affected by heat exposure is called thermal decomposition [12]. The instantaneous decomposition rate (weight loss rate), the reflection of the weight loss, is a function of the Aluminum fraction that is not decomposed [9].

Activation energy is the minimum energy that must be present in a chemical system to carry out a chemical reaction and to determine the amount of activation energy required for thermal decomposition of the material in the decomposition process using TGA. The thermal decomposition of certain metal materials results in an increase in the mass of the material from its initial mass. This happens when the temperature is high. The sample will react with the atmosphere and form a new layer [9].

The results of the TGA test can be further processed to obtain patterns and parameters of thermal decomposition kinetics by using the Arrhenius equation formulated in 1889 [5].

The TG curve is the product of TGA, which is the ratio between changes in mass to temperature. The Y-axis is the percentage change in the mass of the material, while the X-axis is the increase in the temperature value. On the Y-axis, you can also enter the time. The TG curve can be used to express the sample's purity and determine the sample's transformation at a specific temperature range [13]. By increasing the temperature to 700°C, the oxidation rate will decrease because Aluminum's melting point is at a temperature of 660°C [14].

The activation energy is calculated before the melting point or at a certain temperature region where decomposition of the material occurs during heating. In contrast, the melting point of the alloy material is obtained by using (DTA-Differential Thermal Analyzer) from the TGA/DTA program.

2. METHODOLOGY

The initial preparation is the purchase of materials on the free market, namely pure Aluminum and white tin. The next step is casting and printing the research material, namely pure Aluminum, aluminum mixed with 2%, 6% and 10% tin. Then casting is carried out, the stage of making research samples, and some of the frozen material in the mould is removed. Each material is sawed into powder form, then the process of cleaning iron powder from the hacksaw using a magnet will be carried out, then it will be a research sample and ready to be used test. The instrument used in this research is TG/DTA exstal SII 7300 at room temperature up to 900ºC with a constant heating rate (ramp) of 10ºC/min, and the atmosphere is oxygen.

3. RESULTS AND DISCUSSION

After all the tests were completed, the existing data was compiled and processed to obtain the magnitude of the activation and oxidation energy in pure Aluminum and Aluminum mixed with a white tin of 2%, 6% and 10%. The melting point temperature of the aluminum and tin alloys will also be obtained from the data processing.

The calculated data are arranged in tabular form and further processed, then displayed as a Thermogram image (Fig. 1, 4, 7 and 9). TGA will also be able to provide measurement data for the melting point of Aluminum alloys.

3.1. Pure Aluminum

Fig. 1 shows that heating reduced the mass to 14.5 micrograms, which increases in mass as indicated by an increase in the curve. The maximum mass is reduced to a temperature of 174 ^oC and a time of 15.5 minutes. The mass decrease is because of water content on the surface or shell and small dirt in samples. In contrast, the upward trend of the curve is due to the addition of oxygen mass, where the oxidation decomposition begins and approaches the melting point of Aluminum.

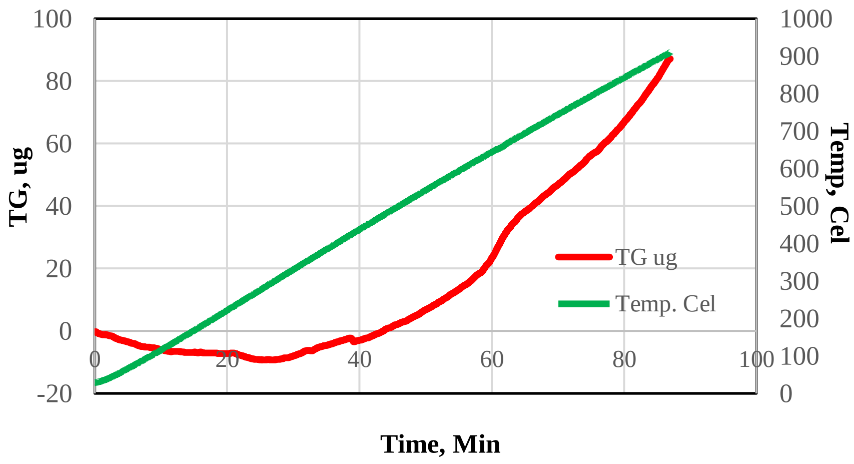

Fig. 1. Thermogram of changes in mass, time and temperature of Al Pure.

Fig. 2 shows that the DTA from the test results of pure Aluminum samples that Aluminum has a melting point at a temperature of 656.2 °C in the liquidus phase. The liquidus phase is the phase between liquid and solid. At temperatures between 537-645 °C, there is an increase in mass due to the addition of oxygen continuously with a stable continuous curve so that the curve against temperature and time becomes one curve.

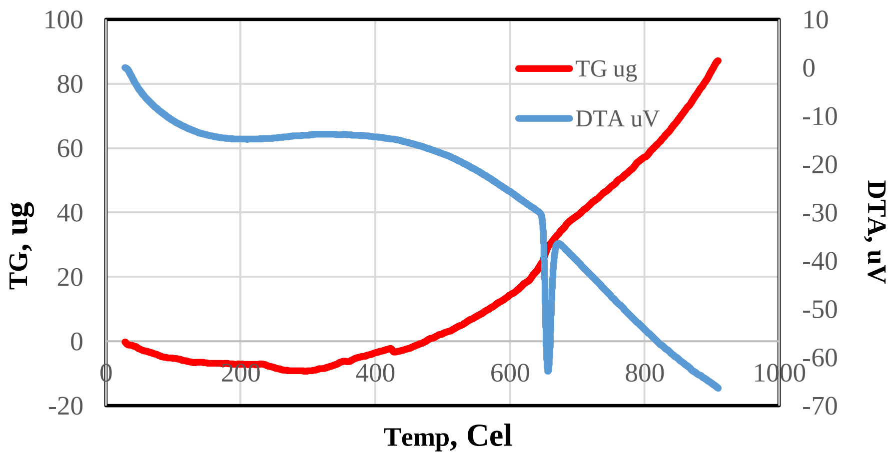

Fig. 2. Melting Point of Pure Aluminum.

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A relationship curve is made between ln k to 1/T to calculate the amount of activation energy. Fig. 3 shows a linear line between ln k and 1/T; this curve can calculate the activation energy.

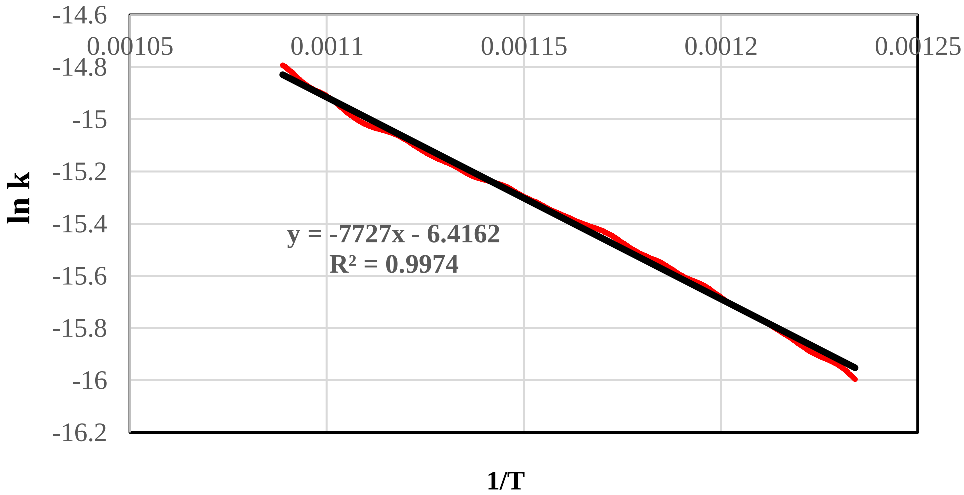

Fig. 3. Relationship of ln k vs 1/T for Pure Aluminum.

From Fig. 3, the straight line function of the Arrhenius equation with a confidence level of R^2 with a scale of 0-1, the value of R^2 in Figure 3 is 0.9974 with a linear line y = -7727x - 6.4162. Therefore, the activation energy obtained is 64.24 kJ/mol.

3.2. Sample 98% Al + 2% Sn

From Fig. 4, it can be seen that the heating given to the sample has reduced the mass by 30 micrograms, and then there is an increase in mass indicated by an increase in the curve. The maximum mass is reduced to a temperature of 329.6 ^{o}C. Looking at the melting temperature of tin, which is 232 ^{o}C, then the mass lost is the mass of water and impurities with a small portion of the mass of tin. Most of the large mass of tin continues to undergo the melting process to reach the boiling point at a temperature of 2625 ^{o}C. The upward trend of the curve is due to the addition of oxygen mass, where the oxidation decomposition begins and approaches the melting point of the Aluminum alloy with 2% Sn.

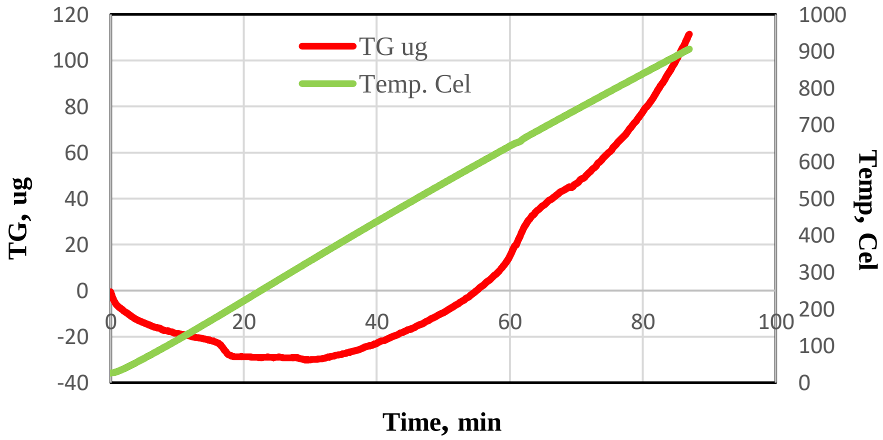

Fig. 4. Thermogram of change in mass, time and temperature 98% Al + 2% Sn.

From Fig. 5, the results of testing samples of pure Aluminum alloys and 2% tin (Sn) show that this alloy has a melting point at a temperature of 655.5 °C in the liquidus phase, which is the phase between liquid and solids. At a temperature of 405-550 °C, an increase in mass is a constant so that the rate of temperature and time becomes one curve.

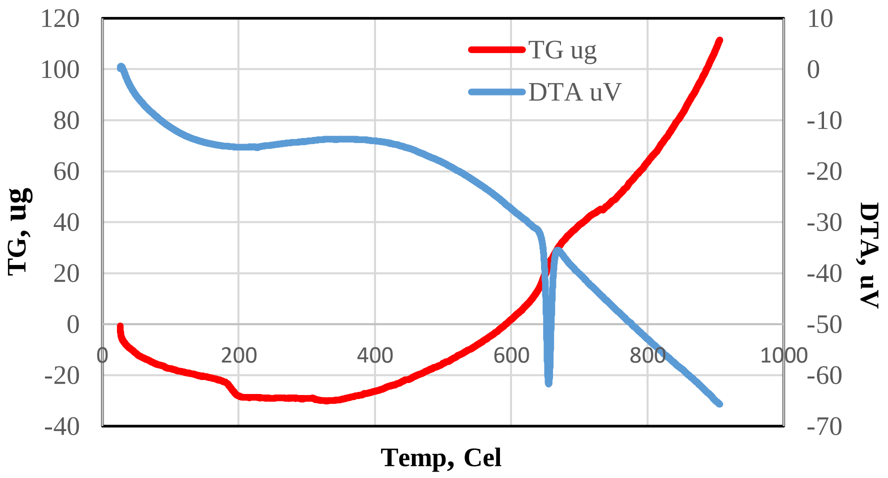

Fig. 5. Melting Point of 98% Al + 2 % Sn.

A relationship curve is made between ln k to 1/T to calculate the amount of activation energy. Fig. 6 shows a linear line between ln k and 1/T, from this curve the activation energy can be calculated.

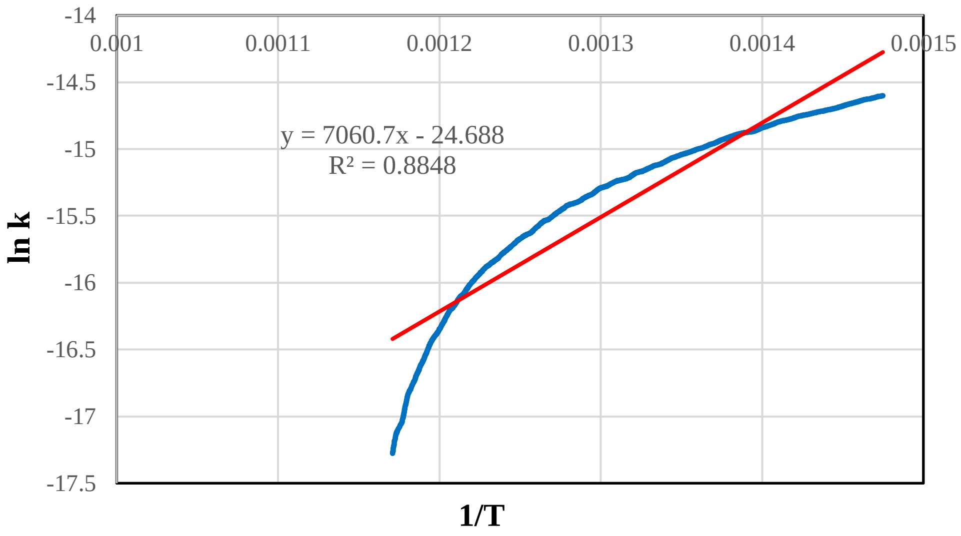

Fig. 6. Relationship of ln k vs 1/T for 98 % Al + 2 % Sn.

In this case, the trendline function can be used to determine the level of confidence, namely $R^{2,}$ with a scale of 0-1; the R^2 in the graph above is 0.9592 and the linear trendline y = 7060,7x - 24,688 So that the activation energy is 58,70 kJ/mol.

3.3. Sample Al + 6% Sn

From Fig. 7, it can be seen that the heating given to the sample has reduced the mass by 78 micrograms, and then there is an increase in mass indicated by an increase in the curve. The maximum mass is reduced to a temperature of 471.6 °C or up to 43 minutes. Considering the melting temperature of tin is 232 °C, the mass lost is the mass of water and impurities with a small mass of tin. Most of the large mass of tin continues to undergo the melting process to reach the boiling point at a temperature of 2625 °C. The upward trend of the curve is due to the addition of oxygen mass, where the oxidation decomposition begins and approaches the melting point of Aluminum alloys with 6% Sn.

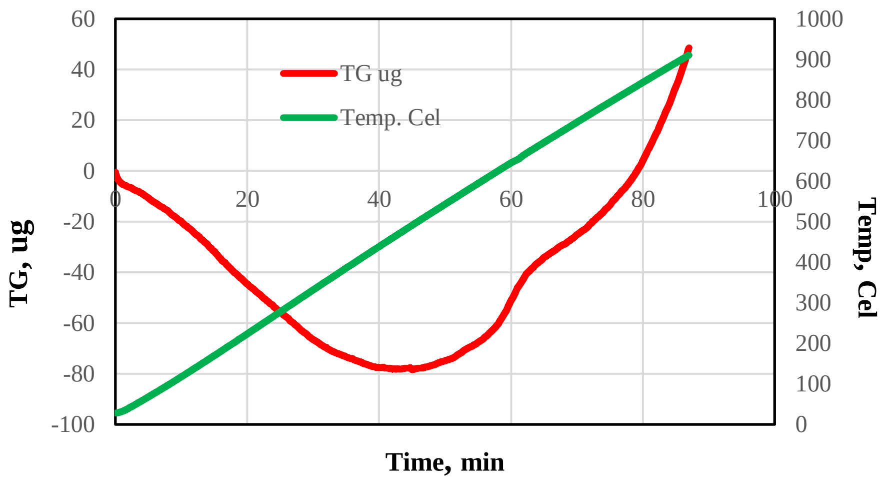

Fig. 7. Thermogram of mass increase, time and temperature 94% Al + 6% Sn.

From Fig. 8, a mixture of pure Aluminum and 6% tin (Sn) shows that the 94% Al +6% Sn alloy has a melting point temperature of 655℃ in the liquidus phase, the liquidus phase is the phase between liquid and solid. Also, at a temperature of 450-600 ℃, mass increase due to the addition of oxygen continuously so that the rate curve concerning temperature and time becomes one curve.

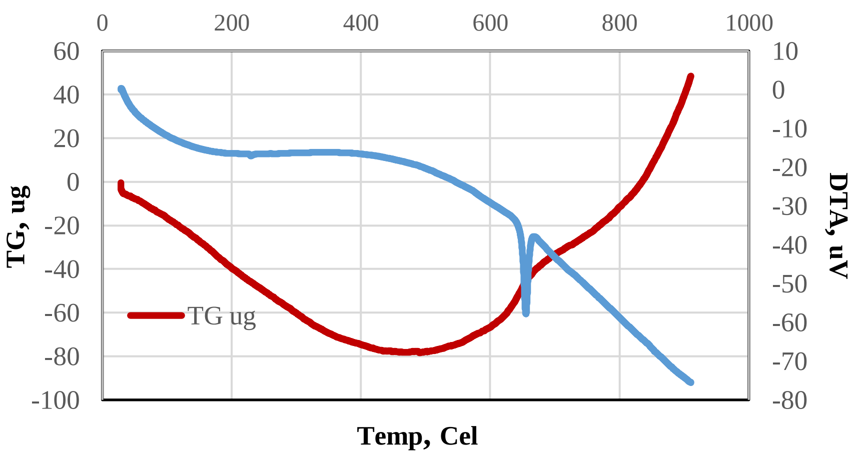

Fig. 8. Melting Point of 94% Al + 6% Sn.

A relationship curve is made between ln k to 1/T to calculate the activation energy amount. Fig. 8 shows a linear line between ln k and 1/T; the activation energy can be calculated from this curve.

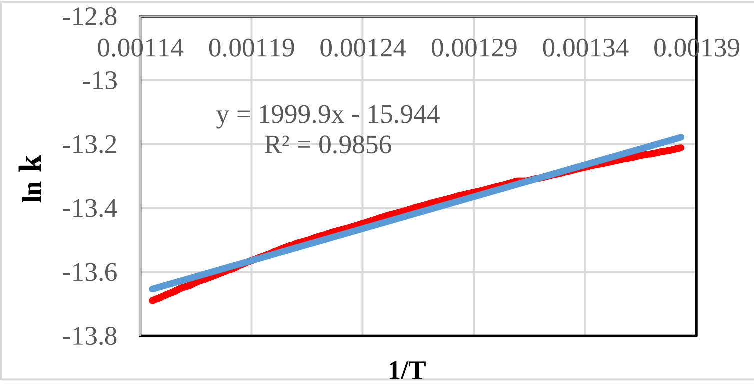

Fig. 9. Relationship of ln k vs 1/T for 94 % Al + 6 % Sn.

In this case, the trendline function can be used to determine the level of confidence, namely R^2 with a scale of 0-1; the R^2 in the graph above is 0.9856 and the linear trendline y = 1999,9x - 15,944 so that the activation energy is 16.63 kJ/mol.

3.4. Sample Al + 10% Sn

Fig. 10 shows that the heating given to the sample has reduced the mass by 15 micrograms, and then there is an increase in mass indicated by an increase in the curve. The maximum mass is reduced at a temperature of 106 °C or up to the 9th minute. In this case, there is no visible effect of the melting of lead; the mass lost is the mass of water and impurities. The upward trend of the curve is due to the addition of oxygen mass, where the oxidation decomposition begins and approaches the melting point of the Aluminum alloy with 10% Sn.

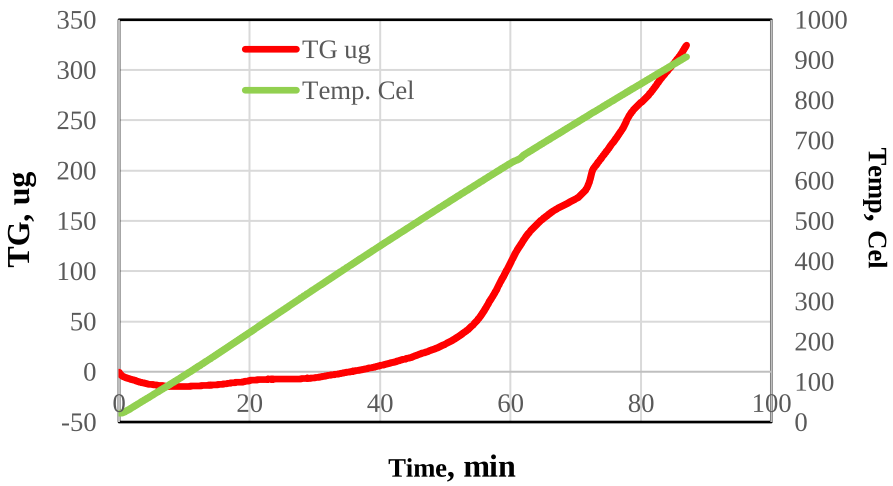

Fig. 10. Thermogram of mass increase, time and temperature 90% Al + 10% Sn.

From Fig. 11, an alloy of 90% pure Aluminum and 10% tin (Sn) can be seen that Aluminum has a melting point at a temperature of 653.5 °C in the liquidus phase, the liquidus phase is the phase between liquid and solid, precisely at a temperature of 450-627 °C. Mass increase due to the addition of oxygen continuously so that the rate of the curve concerning temperature and time becomes one curve.

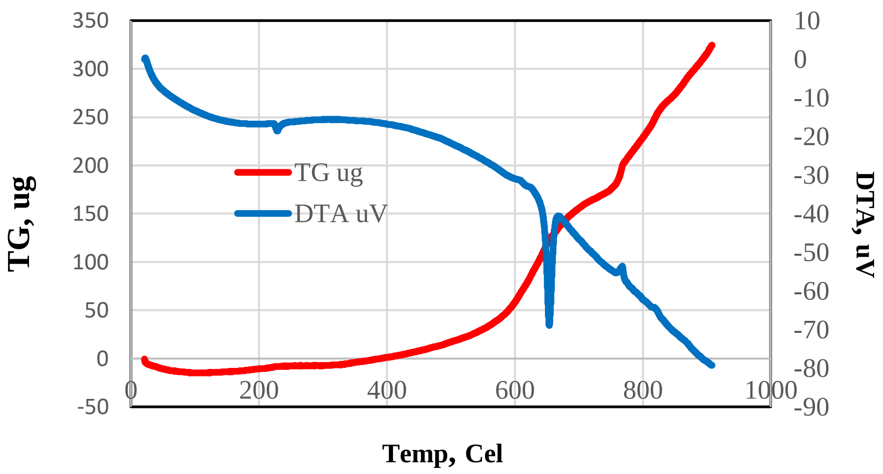

Fig. 11. Melting Point of Alloy 90% Al + 10% Sn.

A relationship curve is made between ln k to 1/T to calculate the amount of activation energy. By using the excel program, this curve can be created. Fig. 11 shows a linear line between ln k and 1/T. From this curve, the activation energy can be calculated.

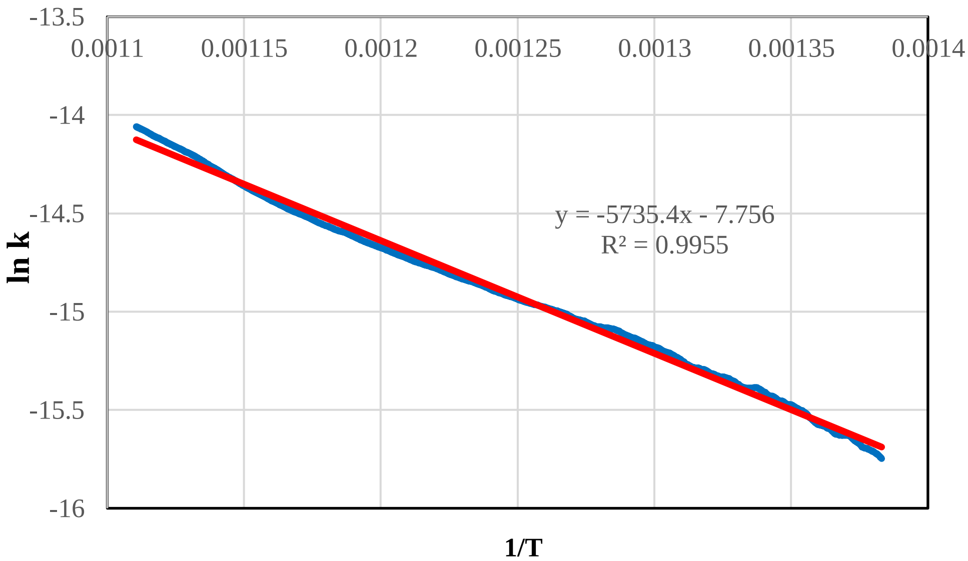

Fig. 12. Relationship between ln k vs 1/T for 90% Al + 10% Sn.

In this case, the trendline function can be used to determine the level of confidence, namely $R^{2,}$ with a scale of 0-1; the R^2 in the graph above is 0.9955, and the linear trendline y = -5735.4x - 7.756 so that the activation energy is 47.68 kJ/mol.

4. CONCLUSION

The following conclusions were obtained based on data processing from the results of testing research samples of pure aluminum and aluminum mixed with white tin by the TGA tool. In the TGA test results curve for all samples, including pure Al, the initial mass reduction before the oxidation process was caused by the release of water vapour and impurities trapped in the skin of the sample. The activation energy required for the oxidation process for pure Aluminum of 64.24 kJ/mol; a mixture of pure Aluminum and 2% tin of 58.70 kJ/mol; a mix of Aluminum and 6% tin of 16.63 kJ/mol; and the sample mixture of pure Aluminum and 10%

tin of 47.68 kJ/mol. Based on the calculation of the activation energy, pure Aluminum samples generally require greater activation energy than other samples. In the second point, it is proven that adding white tin to Aluminum can affect the activation energy required; with white tin, the activation energy required for the oxidation process will be smaller. There is no discussion at temperatures above 600℃ because the sample has melted, and the rate of mass increase is very far away.

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