Measurement of Thickness by Radiation Method

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Abstract

In this work, the thickness of various aluminium sheets is determined by using the Geiger-Muller (GM) radiation detector. For this procedure, the beta source ^{90}Sr (strontium) was used. The standard absorber calibration curve is constructed by using the measured data. And also the determination of the thickness was calculated by using the absorber calibration curve. Besides the standard absorber calibration curve is fitted with (linear, on a different scale). The coefficient of determination R^2 value is close to 1. The results of slide caliper measurement and the radiation technique measurement are nearly equal.

***Keywords**: beta source, aluminium, absorber, calibration curve, radiation technique*

1. Introduction

Nuclear techniques are increasingly used in industry and environmental management. The continuous analysis and rapid response of nuclear techniques, many involving radioisotopes, mean that reliable flow and analytic data can be constantly available. This results in reduced costs with increased product quality [1].

The nucleus of a radioisotope usually becomes stable by emitting alpha and/or beta particles. These particles may be accompanied by the emission of energy in the form of electromagnetic radiation known as gamma rays. This process is known as radioactive decay [2]. Radioisotopes have very useful properties: radioactive emissions are easily detected and can be tracked until they disappear leaving no trace.

Manufacturers use radioisotopes to improve the quality of goods in thousands of industrial facilities around the world. Radioactive materials also are used in industry to inspect metal parts and welds for defects; to measure, monitor, and control the thickness of sheet metal, textiles, paper napkins, newspapers, plastics, photographic film, and other products [3].

In the present research, the unknown thickness of aluminium sheets was determined by the radiation method. The Geiger Muller counter is used for intensity measurements of experimental study. The standard radioisotopes of ^{90}Sr are used in the measurement. The density of aluminium and the thickness of aluminium have been determined. The results have been presented in a graphical form by using Microsoft Excel 2013.

2. Material and Method

2.1. Measurement for Density of Aluminium Sheet

Firstly, to determine the density of each aluminium sheet the length (l), breadth (b), and thickness of each sheet was carefully measured with slide caliper (at least count LC = 0.001 mm) and the mass of each sheet was determined by using an electronic digital balance. This procedure was made ten times.

For each sheet, density value and its average value is calculated by using this measured data. According to the different places of the sheet to measure the length, breadth, and thickness were counted ten times to reduce the statistical errors.

Table 1 shows the density data of eight sheets of aluminium sheets. The uses of slide caliper and aluminium sheet are shown in Figure 1.

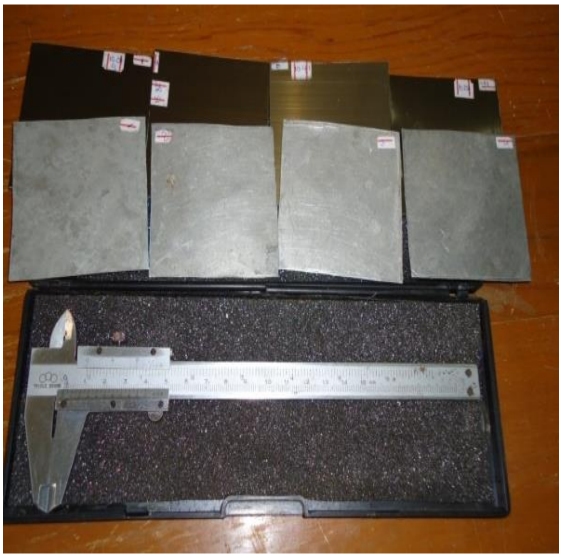

Figure 1. The Uses of Slide Caliper and Aluminium Sheet

Table 1. The Density Data of Eight Sheets of Aluminium

No	Dimensions				Density (ρ) (g cm^{-3})
	l (cm)	b(cm)	t(cm)	m (g)	
1	6.9	7.1	0.03	4.96	2.83
2	7.2	6.9	0.03	4.97	2.85
3	7.3	6.8	0.1	8.25	1.66
4	6.7	6.8	0.1	8.49	1.89
5	6.9	6.8	0.1	10.4	2.23
6	6.9	7	0.1	12.5	2.61
7	7.3	7.2	0.10	15.8	2.88
8	7.1	6.9	0.11	16.0	2.94
Average Density (ρ) (g cm^{-3})					2.486
Pure Aluminium Density (ρ) (g cm^{-3})					2.7

2.2. Thickness Measurement for GM Counting

In this measurement, the Geiger-Muller Counter (ST-360) with scaler installed with PC, aluminium absorber set) absorber slide, digital balance (sensitive to 0.01g), slide caliper, and collimated beta source ^{90}Sr (µCi) were used. The measurement condition for the experimental setup is as shown in Figure 2. The operating voltage of such GM counter is 950V. The power supply was adjusting at the operating voltage. The background counting rate was measured. The empty absorber slide is placed on the fifth shelf to ensure constant geometry.

And then the collimated beta source ^{90}Sr is placed on the fifth shelf of the tube stand without absorber. The counts were recorded. The thinnest absorber is inserting on the absorber slide, the counts were recorded and measured with the other absorbers, going from the thinnest to the thickest. The counting time was 60 sec for each measurement.

The aluminium sheet was placed (fitting in absorber slide or frame) having the smallest value of mass per unit area, above the source and below the Geiger tube at a fixed point as shown in Figure 2 and the counting rate keeping the same operating voltage. All the pieces of the aluminium sheet were measured above the procedure. All measured data are stored in the PC. At the end of the measurement, the background counting rate is measured.

Figure 2. The Measurement Condition for Experimental Setup of Geiger-Muller Counter (ST-360)

3. Data Analysis

The observed counts of the ten samples of the standard aluminium absorber are shown in Table 2. These data are used to construct a calibration curve by plotting the corrected count on the y-axis against absorber thickness in mg cm^{-2} on the x-axis. These data were used to make the absorber calibration curve. The absorber calibration curve (exponential scale) is shown in Figure 3.

Since absorber thickness is defined as the product of the density and thickness and express as

Absorber Thickness (mg cm^{-2}) = Density x Thickness

The above equation may be used to determine the thickness of the aluminium sheet [4]. The absorber thickness is found from the calibration curve. The density of aluminium is found from a handbook [5]. To compare the accuracy of these results, the sheet thickness may be taken with a caliper.

Table 2. Observed Counts of the ten Sheets of Standard Aluminium Absorber

Absorber Thickness (mg cm^{-2})	Observed Counts (cpm)	Corrected Counts (cpm)
0	3486	3450±0.39
141	2150	2114±0.31
170	1930	1894±0.29

Table 2. Continued

216	1650	1614±0.26
258	1321	1284±0.23
328	892	856±0.19
425	482	446±0.14
522	239	202±0.09
645	161	124±0.07
655	88	52±0.48
840	47	11±0.02

The average background count is 36 cpm.

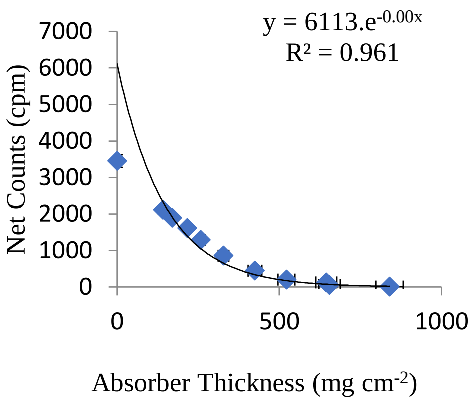

Figure 3. The Standard Absorber Calibration Curve (Exponential Fitting)

4. Results and Discussion for Thickness Measurement

In this experiment, the measured data are used to draw the standard absorber calibration curve. The standard absorber calibration curve is shown in Figure 4. This curve gives the relation between the net counts (log scale) and the absorber thickness. According to these linear curve fitting y = - 0.003x+ 3.786 and the R^2 value is 0.961.

Similarly, the relation between the net counts (ln scale) and the absorber thickness is used to draw the curve. This curve can be made by linear curve fitting. The calibration curve is shown in Figure 5. According to these liner curves fitting y = -0.006x+8.718 and the R^2 value is 0.961.

And also the measured data are used to draw the relation between the net counts (ln I/I_o scale) and the absorber thickness. According to these linear curve fitting y = -0.006x + 0.572 and the R^2 value is 0.961. The calibration curve is shown in Figure 6. According to these curve fitting, the R^2 value is close to 1. The comparison of R^2 values for different scale is shown in Table 2.

In this measurement, a semi-log graph uses a logarithmic scale on the vertical axis and a linear scale on the horizontal axis. Plotting a graph taking x the thickness of aluminium absorber in mgcm^{-2} along the x – axis and corresponding value of $\log_{10}$ I along Y-axis. And then, by plotting the net counts of aluminium sheet is placed on the y-axis. From the count of the aluminum sheet, we determine its absorber thickness on the calibration curve. These results are shown in Table 3.

According to Table 4, the aluminum absorber is measured with a slide caliper and then the aluminum absorber is measured by radiation method. This measurement result is calculated by comparing it to the Absorber Calibration Curve (Logarithmic Scale) shown in Figure 7.

From Table 2, the absorber thickness (surface density, mg cm^{-2}) was used to calculate the thickness (x, mm) of the aluminium sheet. These results are shown in Table 5.

According to this graph, the value half-thickness is 200 mg cm^{-2} and the absorption coefficient μ of aluminium for beta particle is 0.003465 cm^{-1}.

This value is nearly equal to the other measurement data. Therefore a graph between $\log_{10}$ I and x is a straight line and the slope of the line gives the value of μ the absorption coefficient of the material with a negative sign. This value is agreed with the linear fitting curve (Net Counts log scale vs Absorber Thickness) of the slope y = - 0.003x+ 3.786.

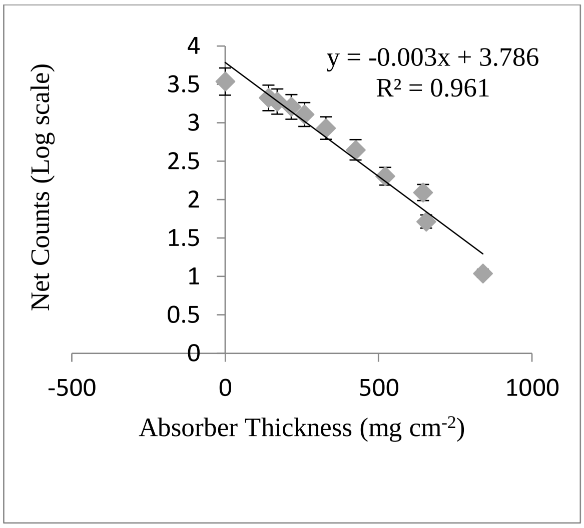

Figure 4. The Standard Absorber Calibration Curve (Log Scale)

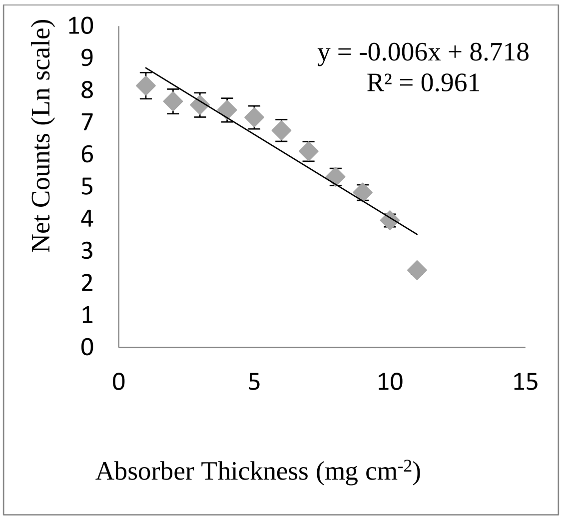

Figure 5. The Standard Absorber Calibration Curve (Ln Scale)

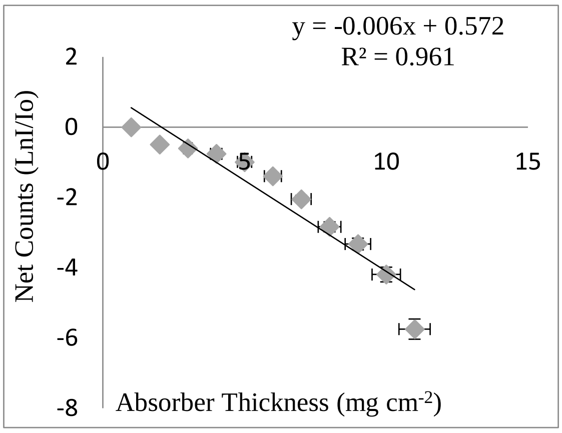

Figure 6. The Standard Absorber Calibration Curve (LnI/Io Scale)

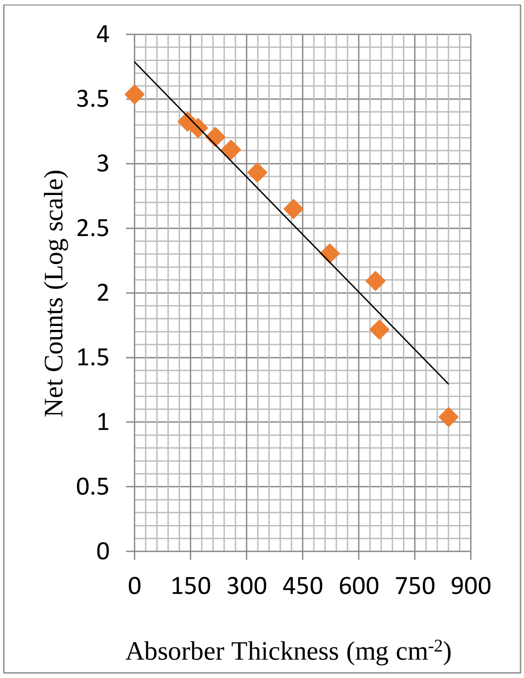

Figure 7. Standard Absorber Calibration Curve and Analysis Data

Table 3. The Comparison of R^2 Values for Different Scale

Linear Fitting (Log scale)	Linear Fitting (Ln scale)	Linear Fitting (Ln I/Io)
0.961	0.961	0.961

Table 4. Calculated Values of Thickness of Aluminium Absorber (Using Absorber Calibration Curve by Semilog Paper)

Sheet Number	Thickness (mg cm^{-2}) Slide Caliper	Thickness (mg cm^{-2}) Radiation Technique
1	84 ± 0.06	100 ± 0.06
2	99.7 ± 0.06	155 ± 0.08
3	166 ± 0.06	159 ± 0.08
4	189 ± 0.09	185 ± 0.09
5	223 ± 0.09	200 ± 0.10
6	261 ± 0.12	242 ± 0.11
7	302 ± 0.12	275 ± 0.11
8	323 ± 0.13	353 ± 0.12

Table 5. The Thickness (x, mm) of the Aluminium Sheet

Sheet No	Thickness (**mm**) (Slide Caliper)	Thickness (**mm**) Radiation Technique
1	0.3±0.003	0.37±0.004
2	0.35±0.003	0.57±0.005
3	1.0±0.005	0.58±0.005
4	1.0±0.005	0.68±0.005
5	1.0±0.005	0.74±0.005
6	1.0±0.005	0.89±0.006
7	1.05±0.006	1.02±0.006
8	1.1±0.006	1.31±0.007

5. Conclusion

In this research work the Strontium (^{90}Sr) as a thickness gauge and it is the highest energy beta source. A beta source is placed on one side of a sheet of material. Beta absorption measurement is very effective for non-destructive investigation of defects in the various sheets of other substances, depth of the cup, density of the material, and strain of string.

This idea is also used to control production lines of paper, plastic, or steel sheeting. The detector signal is checked against that for a preset thickness.

It is found that the results of slide caliper measurement and the radiation technique measurement are nearly equal.

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References

[1] G.D Chase, *"Thickness Gauging"* Courtesy of Atomic Accessories, Inc, USA.

[2] Kaplan, Irving, "*Nuclear Physics*", 2nd Edition,Addison-Wesley Company, (1962).

[3] "*Uses of Beta Radiation Sources*" http:www.wikipedia.com/the free encyclopedia

[4] "*Measurement of Thickness by Beta Transmission Gauge"* EXPT.No.6.

[5] G. Audi and A.H. Wapstra, *"The Atomic Mass Evaluation (I) Atomic Mass Table"* (1993).