GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

DEVELOPMENT OF GAMMA-BASED NONDESTRUCTIVE TESTING SYSTEM FOR THICKNESS MEASUREMENT

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ABSTRACT

In this work, a simple gamma transmission-based non destructive system has been developed for scanning thickness defects in flat rolled products and discriminated samples with respect to their density. Based on radiation attenuation, the study involved the measurement of the thickness in centimeters scales for a flat sheets of Alumina ceramic, borated glass, aluminum and iron. The practicality of using the system to detect thickness flaws in millimeter range was calculated considering a scenario that a thickness change by 1mm is present along the sheet of each sample. This is done through the assessment of the degree of transmitted attenuation experienced by a beam of high energy ionizing radiation, such as 241Am directed perpendicular to the planar surface of the material. The results confirmed the sensitivity of the system for detection of flaws in both thickness scales.The sensitive of the system is about 1mm .

Keywords: *Gamma, Nondestructive testing system, Thickness measurement etc.*

I. INTRODUCTION

Precise, accurate measurement of sheet thickness is critical in the controlled processing and quality assessment of flat rolled metal products. Through the years, many non destructive methods have been developed, each having specific, relevant applications, and certain characterizable advantages and disadvantages, [1-3]. These systems are provided in a variety of geometries and physical arrangements.

Probing is defined as the investigation of a particular location. Inspection provides an overall assessment that need not be location-specific. Monitoring is a passive process of probing or inspection. The probing process is particularly helpful in detecting discontinuities caused by abnormal thickness changes in the examined material. Unlike gauging and elemental analysis, probing and inspection do not necessarily provide quantified information. Therefore, probing and inspection can be seen as assessment tools for diagnosing the condition of an industrial object or a process.[1-4]

The surface condition of industrial components can be affected by deposition and erosion. For example, corrosion on the inside walls of pipelines and vessels can cause the condition of internal walls to deteriorate, creating safety and operational concerns.

While deposition causes the addition of undesirable material, erosion results in the loss of primary material. Therefore, both processes change the apparent thickness and density of affected walls, or in other words, the areal density (density ×thickness). This makes such measurements particularly amenable to the radiation transmission method discussed in section.[[3-5]

Gamma-ray beam transmission is useful for scanning for thickness defects in flat rolled products. With a narrow (well-collimated) beam, a rapid scan of a wall can be performed to detect changes in the transmission signal, which can be an indication of the occurrence of thickness defaults. Gamma-radiation is particularly useful for such applications due to its high penetrability, ease of collimation, portability (due to the small size of gamma-sources) and mobility (due to the self-powered nature of isotopic sources).[6-11] This research is concerned with using gamma radiation to determine material thickness this done in section (2) and (3) which are concerned with materials and method . sections (4) and (5) are denoted for results and discuss beside conclusion.

II. MATERIALS AND METHOD

The present study is directed to develop and method for gauging the thickness of a moving sheet of industrial products such as; ceramic, glass, aluminum and iron.

A source of penetrative radiation is positioned in such a manner as to provide the radiation beam perpendicularly through the sheet material. A radiation detector is positioned on the opposite side of the sheet material from the radiation source to measure the beam attenuation. The radiation detector is coupled with a signal processing unit which feeds the electrical outputs to a monitor. A processor then determines the thickness of the material based on the values of these outputs. This result is then used to control the rolling mill to provide

ISSN 2348 – 8034
Impact Factor- 3.155

real-time, on-line feedback.It is an advantage of the present invention to require only a single source and a single detector, thereby making the proposed system more cost effective than the conventional solutions. It is a further advantage of the proposed system that only the attenuation of the radiation is required to be measured. This increases the speed and accuracy of the device and reduces the need to have the source and detector in close proximity to the material being measured.

Several measurements were carried out to evaluate the performance of the proposed gamma ray transmission-based sensor for detection of thickness defaults in metallic and non metallic samples such as; Alumina ceramic, Borosilicate glass, Aluminum and Iron. The results were analysed using SigmaPlot10 software,

Based on the measurement procedures discussed in chapter three, here we present the results in terms of transmitted flux with respect to samples under test. The variation of the transmitted flux with energy was also considered to explore the possibility of discrimination between materials under test.

Firstly we used the proposed system to measure the background radiation since it represents an essential factor that should be considered to count the background flux of photons that contribute to our measured transmitted photons from the ^{241}Am source. Figure (1) shows background flux of photons. As presented, the background photon flux peaks at 233 photon.cm^{2}.s^{-1}. The rest of measurements are analyzed considering this value.

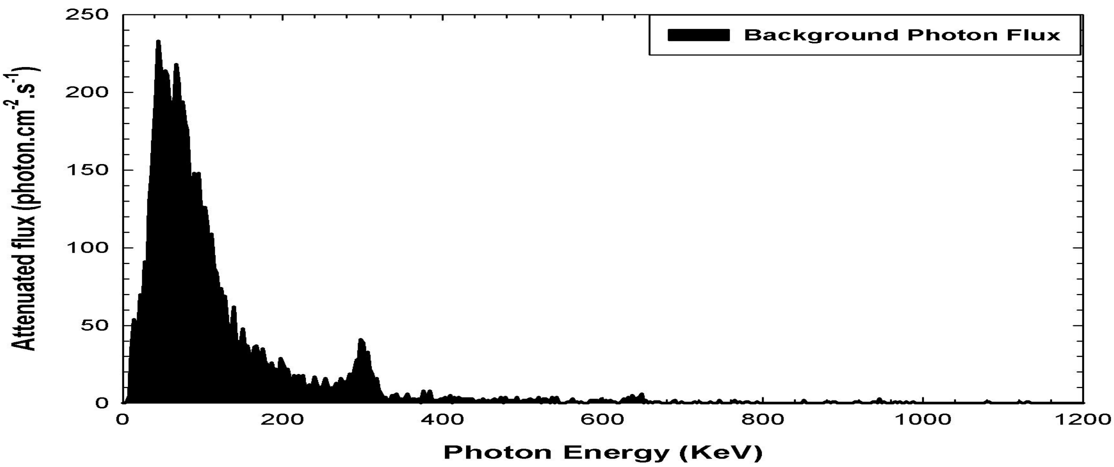

Fig 1. Background flux of photons

III. RESULS AND DISCUSSIONS

The variations of the transmitted intensity with respect to material thickness were presented in tables and figures [(1- a), (1-b)], [1-c),and (1-d)], alumina ceramic , bro-glass aluminum and iron respectively.

(1-a)Alumina Ceramic

Table (1-a) and fig (1-a) shows variation of gamma intensity with thickness

Table .(1-a) Relationship between thickness(t) and transmitted flux I_t for Alumina Ceramic for energy 13KeV (Average density=4.02 g.cm^{-3})

Thickness t ***+0.1cm***	***Transmitted Intensity*** *photon.cm^{-2}.s^{-1}*
1	*3818*
2	*2715*
3	*1756*

ISSN 2348 – 8034
Impact Factor- 3.155

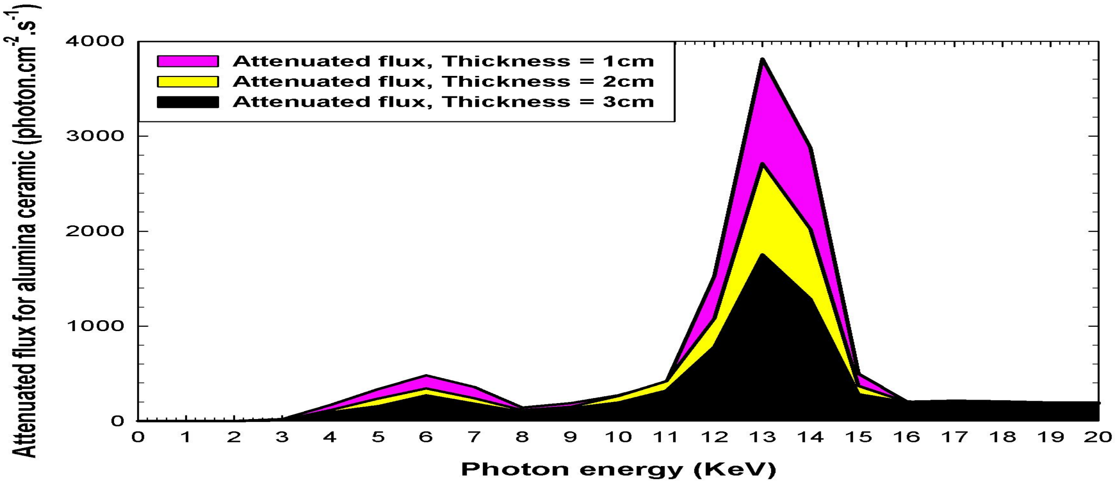

Fig 1.(b) Transmitted intensity as a function of thickness for alumina ceramic

As shown in figure 2.(a) and table (1-a) the transmitted intensity was significantly reduced with the increasing of thickness. This is reasonable since Beer-Lambert law states clearly the transmitted intensity is inversely proportional to the material thickness. The alumina ceramic sample at 1cm, 2cm and 3cm thicknesses has reduced the source intensity (3×10^4) the source energy line (60KeV) approximately by factors of 7, 11 and 17, respectively.

(1-b)Borosilicate Glass

Table (1-b) and fig (1-b) shows variation of gamma intensity with thickness

Table (1-b)Relationship between thickness(t) and transmitted flux I_t for Borosilicate glass energy 40KeV (Average density=2.6 g.cm^{-3})

Thickness ***+0.1cm***	***Transmitted Intensity*** *photon.cm^{-2}.s^{-1}*
1	*3702*
2	*2450*
3	*1543*

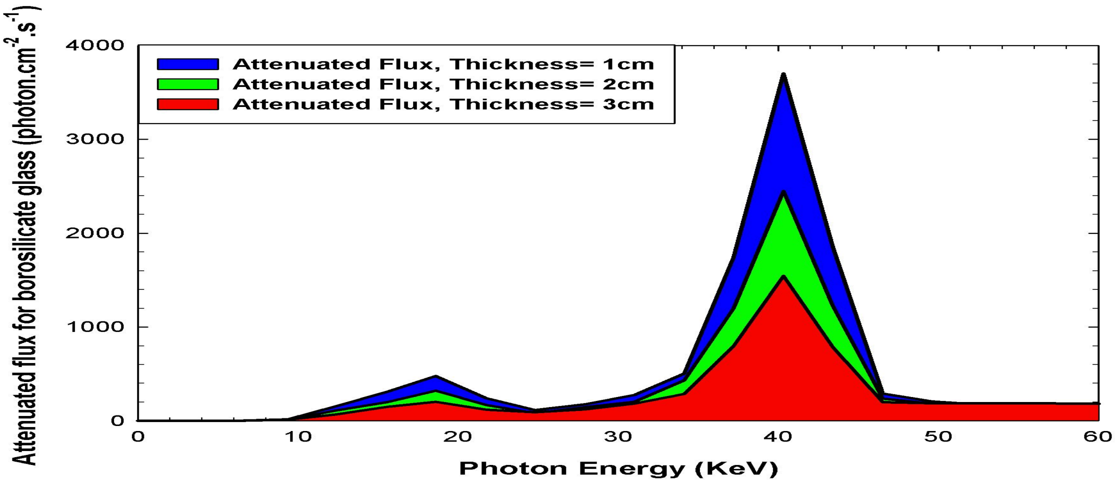

Fig. (1-b)Transmitted intensity as a function of thickness for Borosilicate glass

As shown in figure1-b) and table (1-b) the transmitted intensity was significantly reduced with the increasing of thickness. This is reasonable since Beer-Lambert law states clearly the transmitted intensity is inversely proportional to the material thickness. The borated glass sample at 1cm, 2cm and 3cm thicknesses has reduced the source intensity (3×10^4) the source energy line (60KeV) approximately by factors of 8, 12 and 19, respectively.

(1-c)Aluminum

Table (1-c) and fig (1-c) shows variation of gamma intensity with thickness

Table (1-c)Relationship between thickness(t) and transmitted flux I_t for Aluminum for energy 20KeV (density=2.7 g.cm^{-3})

Thickness ***+.o1cm***	***Transmitted Intensity*** *photon.cm^{-2}.s^{-1}*
1	*3591*
2	*1983*
3	*1196*

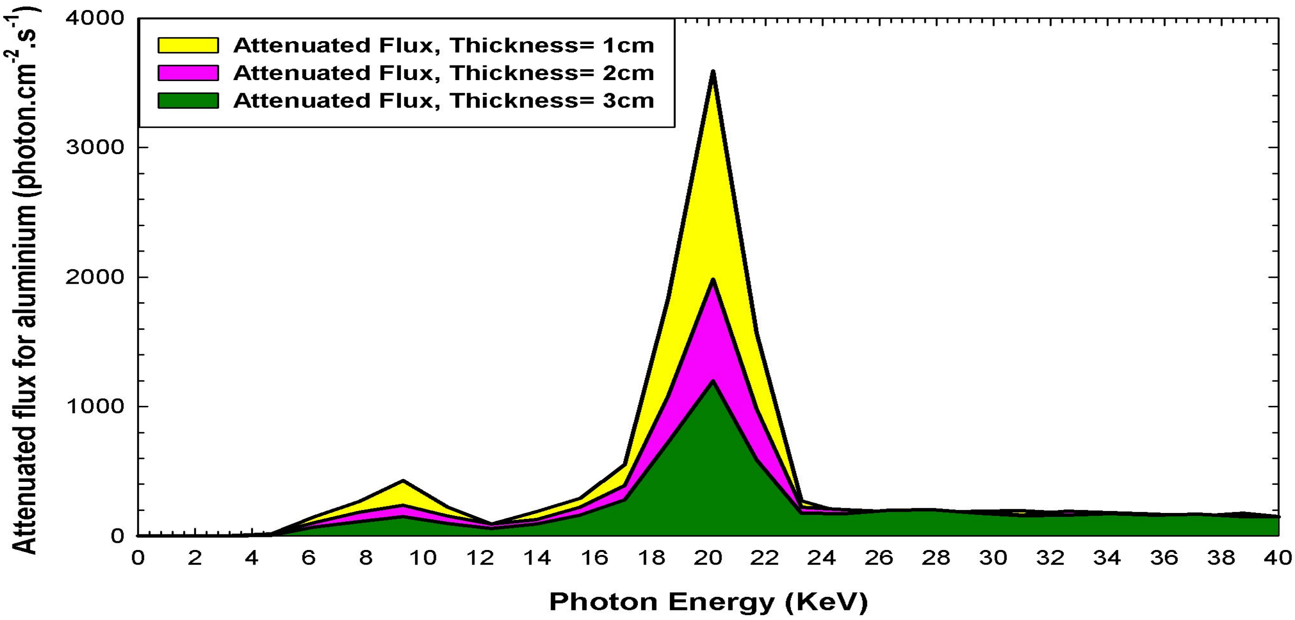

Fig. (1-c)Transmitted intensity as a function of thickness for Aluminum

As shown in figure(1-c). and table (1-c) the transmitted intensity was significantly reduced with the increasing of thickness. This is reasonable since Beer-Lambert law states clearly the transmitted intensity is inversely proportional to the material thickness. The Aluminum at 1cm, 2cm and 3cm thicknesses has reduced the source intensity (3×10^4) the source energy line (60KeV) approximately by factors of 8, 15 and 25, respectively.

ISSN 2348 – 8034
Impact Factor- 3.155

(1-d) Iron

Table (1-d) and fig (1-d) shows variation of gamma intensity with thickness

Table (1-d)Relationship between thickness(t) and transmitted flux I_t for Iron for energy 17KeV for (Density=7.9 g.cm^{-3})

Thickness ***+0.1cm***	***Transmitted Intensity*** *photon.cm^{-2}.s^{-1}*
1	*222*
2	*179*
3	*129*

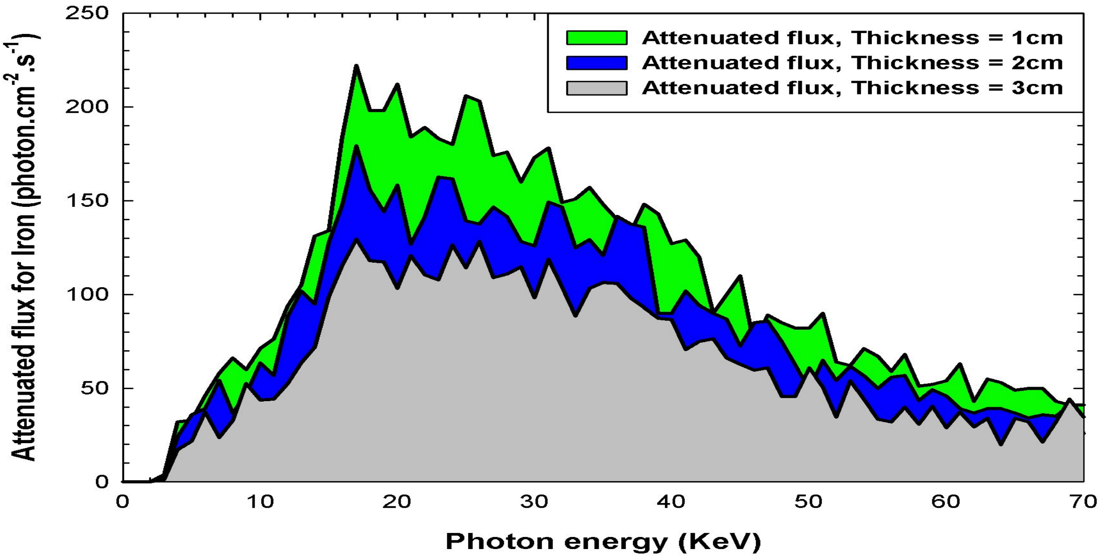

Fig.(1-d).Transmitted intensity as a function of thickness for Iron

As shown in figure 91-d)and table (1-d) the transmitted intensity was significantly reduced with the increasing of thickness. This is reasonable since Beer-Lambert law states clearly the transmitted intensity is inversely proportional to the material thickness. The Iron sample at 1cm, 2cm and 3cm thicknesses has reduced the source intensity (3×10^4) the source energy line (60KeV) approximately by factors of 135, 167 and 232, respectively.

The objective of research was to develop a simple gamma transmission-based non destructive system and explore its practicality in providing a precise and accurate thickness measurement of flat rolled products such as; ceramic, glass, aluminum and iron. The research was also oriented to explore the possibility of using such system to discriminate samples with respect to their density. The proposed system is composed of ^{241}Am photon source, NaI(Tl) scintillation detector, signal processing unit, shielding and a monitor.

The results confirmed the sensitivity of the system for detection of flaws in both thickness scales. The alumina ceramic sample at 1cm, 2cm and 3cm thicknesses has reduced the source intensity (3×10^4) the source energy line (60KeV) approximately by factors of 7, 11 and 17, respectively. While at 9mm and 11mm thicknesses has reduced the source intensity (3×10^4) the source energy line (60KeV) by factors of 5 and 11, respectively. The borated glass sample at 1cm, 2cm and 3cm thicknesses has reduced the source intensity (3×10^4) the source energy line (60KeV) approximately by factors of 8, 12 and 19, respectively. While at 9mm and 11mm thicknesses has reduced the source intensity (3×10^4) the source energy line (60KeV) approximately by factors of 7 and 8.8, respectively.

The Aluminum at 1cm, 2cm and 3cm thicknesses has reduced the source intensity (3×10^4) the source energy line (60KeV) approximately by factors of 8, 15 and 25, respectively. While at 9mm and 11mm thicknesses has reduced the source intensity (3×10^4) the source energy line (60KeV) approximately by factors of 3.4 and 20.3, respectively. The Iron sample at 1cm, 2cm and 3cm thicknesses has reduced the source intensity (3×10^4) the source energy line (60KeV) approximately by factors of 135, 167 and 232, respectively. While at 9mm and 11mm thicknesses has reduced the source intensity (3×10^4) the source energy line (60KeV) by factors of 100 and 181, respectively.

IV. CONCLUSION

These results demonstrate clearly the possibility of using the proposed gamma-transmission- based sensor for thickness detection in millimeters ranges. A change by 1mm for all four samples produced detectable transmitted flux.

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