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Measurement of linear attenuation coefficient of iron by radiographic method

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Abstract

Application of cargo scanner systems plays critical role in the non-intrusive inspection of import, export and security controls at borders and customs. Determiningthe linear attenuation coefficient is important in identifying material type, detection capability and image quality recorded by these systems. This parameter depends on the type of material, type of radioactive source and its energy. In this study, the linear attenuation coefficient of iron sheets with thickness of 5, 10 and 15 mm were measured using a cargo scanner system equipped with a cesium 137 gamma ray source with 0.667 MeV energy. The measured values for the samples were compared with reported experimental and therorotiocal values. The results showed a good agreement with each other.

Keywords: Radiography, Attenuation Coefficient, Gamma ray, Cargo scanner setup.

Introduction

Conventional X-ray and gamma-ray detection methods have grown since the 1970s, and inspection of cargo with these radiation generators has quickly become a key tool in customs around the world for national security and to prevent the entry and exit of smuggled and high risk goods. Non-destructive inspection of cargo containers at customs centers, shipping ports and airports are the most useful applications of these devices [1].The correct operation of cargo scanner systems is based on the attenuation of the incident beam by the material and detecting of the attenuated beam by detectors or imaging section. Since the radiation generator in the the most of these systems are X-ray and gamma rays, therefore a parameter called as linear attenuation coefficient has important role in determining the material type [2,3]. In this study the attenuation coefficient of iron plates at 667 keV gamma energy was measured by means of cargo setup. The results of the measurements were compared with the results of the references, which showed a good agreement with each other.

Experimental

Preparation of the materials

When single-energy gamma rays strike an object to be inspected, some or all of them are absorbed and/or scattered due to dominant interaction processes. The fraction of the incident x or gamma rays that is absorbed or scattered characterizes the linear attenuation coefficient of the material. The linear attenuation coefficient depends on depends on the matrial atomic number (Z) and the energy of the incident beam and is explained by the equation (1):

$$I = I_0 e^{-\mu t} \qquad 1$$

where I_0 and I are the initial and final intensities of the photons, respectively, μ is the linear attenuation coefficient with (cm^{-1}) dimention and t is the thickness of the material.

Based on the density of a material, linear attenuation coefficient (μ) used to characterize the penetration and propagation of gamma rays in a given material and is responsible for image quality in medical radiographic systems and non-destructive testing used by industy. non-destructive

In this research, iron plates with dimensions of 30 × 30 cm and thicknesses of 5, 10 and 15 mm was used to test the measurement accuracy of the cargo system in comparision of other method in deterrmining the linear attenuation coefficient of iron as commonly used material.

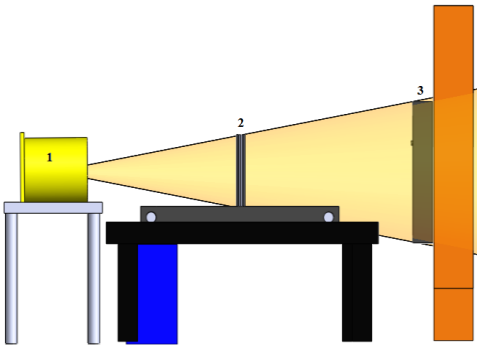


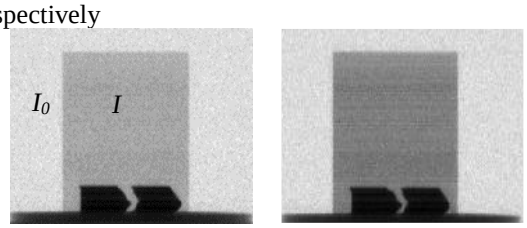
Figure 1. 1-Source, 2-Sample, 3-Detector

Each sample positioned between the source and detector using a conveyor to record radiographic image. The gamma ray reaches the detectors after passing through

the iron sheet. The distance between the iron sheet and the detector was 50 cm and the 128 detectors are arranged in a column. Schematic diagram of the geometry used for measuring the linear attenuation coefficient is shown in Figure 1. This setup consists of three main parts: 1- radioactive source is Cesium 137 source, 2- an array detector system to record the image of the object and 3- the sample under study. The images of the samples were pre-processed, then the value of the linear attenuation coefficient was measured using the developed algorithm in MATLAB.

Results and discussion

The radiograph images of the samples are shown in figure 2 for iron specimens with a thickness of 5 and 10 mm. the initial intensity and the intensity of the esposed objects marked with I_0 and (I) on the image respectively



a b

Figure 2. Radiographic image of iron plates a) 5mm, b) 10mm sample

The intensity distribution along a horizontal line of the radiography images of the iron samples is shown in Figure 3. The plot shows the varaition of the count on the detector with and without the presence of samples with 5, 10 , 15 mm thickness.

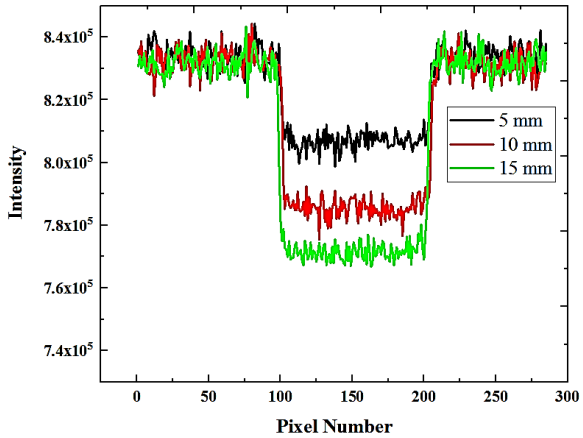


Figure 3. The intensity distribution of a given horizontal line(only for one pixel of the array detector), Black(5 mm), Red(10 mm) and Blue(15 mm) sampels.

Using the MATLAB algorithm the area related to the object (I), and the initial intensity (I_0) are sampeled then the value of linear attenuation coefficient of three samples was measured by the realtion No. 1.

Table1. Measured data

SampleThickness	$\bar{I}_{Matrix}$	$\bar{I}_{0_{Matrix}}$	Measured μ in our study
5	806739±3260	831225±3302	0.598±0.06
10	782872±3211	831201±3124	0.597±0.08
15	760543±3460	836490±3045	0.598±0.06

In Figure 4, the measured values are compared with the reported values[4-6].

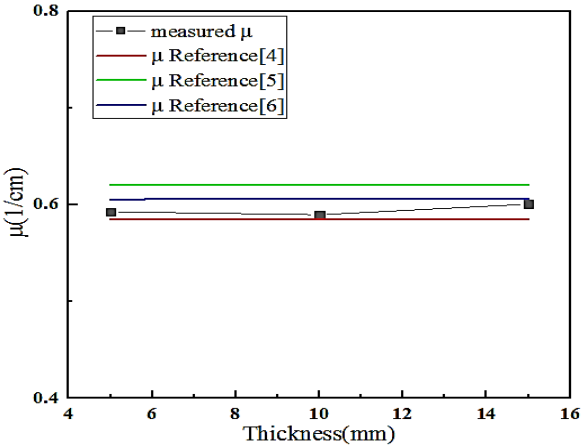


Figure 4. Measured attenuation coeficient

The average of the measured linear attenuation coefficients with the reported value has a standard deviation of about 1%.

Conclusions

In this study, the linear attenuation coefficient of 5, 10, 15 mm iron plate was measured using radiographic method. For this purpose, recorded images and a MATLAB alghorithm were used. The initial intesity of the radiogarphy images was about 8.0×10^5 . The results of linear attenuation coefficient measurements with cargo scanner were in the range of the reported experimental and theoretical results(about($0.6\ \frac{1}{cm}$)).

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