CHAPTER 1

INTRODUCTION

1.1 Background

Non-Destructive Testing (NDT) is defined as testing techniques performed on materials without interfering the subsequent usage of the materials. There are five conventional methods namely, radiography, eddy current, ultrasonic, magnetic particle and liquid penetrant. These methods are used in industrial applications such as for power plants, pipelines in oil and gas, petrochemical industry and also in oil tanks and the body of an aircraft in the aircraft industry.

There are many reasons for using NDT applications. One of the major purposes of conducting the NDT testing is to evaluate the quality of the components used in the related industry after some period of time. This is to prevent any catastrophe, for instance the possibility of an explosion occurring due to fatigue of the materials used. However, a recent term and application being introduced is Non-Destructive Evaluation (NDE) and becoming very popular among NDT community. NDE is different from NDT whereby NDE involves activities such as evaluations, simulations and modelling.

All the five conventional methods are different in their principles, therefore; the application of each method is also different from each other. In determining which test is to be used, factors such as density, thickness, type of materials and easy access to the inspection site need to take into consideration. In principle one should not rely on a single method but use a second method to ascertain the result of the first method. Each method has its own advantages and limitations. Hence, they complement each other in order to produce good and reliable results to the NDT practitioners.

An overview of industrial radiography which includes the basic elements involves in the radiographic system is given in the next section. It is then followed by a section on research motivation and the last section of the chapter will cover the organization of the thesis.

1.2 Industrial Radiography

Industrial radiography method is selected as the method of NDT in this thesis due to the ease of usage and the author has experience dealing with this method. This method also relies on the application of radiation cross section data and this is important for precision measurements. Only industrial radiography method in NDT uses radiation in its application. Traditionally, the industrial radiography testing is only for defect detection and material characterization. However, with precision measurement on cross section data, the industrial radiography method can extend to new area of non contact measurement of test object geometry which includes thickness measurement, external and internal dimensions. Currently, the knowledge on the process model in industrial radiography is very limited especially involving image diffusion on the radiograph. This situation does not permit us to estimate their influence quantitatively. Thus, understanding attenuation coefficient involved in industrial radiography can lead to highly accurate knowledge of the process model that describes the actual phenomena of the complete measurement.

Industrial radiography uses ionising radiation to penetrate the material being tested. Types of ionising radiation used are gamma radiation that comes from a radioactive source and X-ray. Till now, radiography is considered as the most important and most versatile technique. It has vast applications ranging from minute electronic gadgets to mammoth missiles components that are used in the military.

Three basic elements are involved in the setting up the radiography system. They are the radiation source, the material that is going to be evaluated and a recording medium. In the conventional radiography, the recording medium is the film system. However, with the rapid growth and the advancement of the computer, the recording medium has moved to digital detectors for instance, flat panels and imaging plates. Typical types of material that can be tested using radiography are steel and composites. Materials made from steel are usually pipelines as well as plates that are used to build pressure vessels. These components are mainly found in the oil and gas, and petrochemical industries. Materials made from composite are commonly found on aircraft for example at the honeycomb, which is located at the cockpit.

In the industries mentioned, penetration of radiation on material depends highly on the penetration power. The thickness and density of the materials being evaluated play a vital role to determine which radiation should be used in order to obtain a good and acceptable radiograph. When using X-ray machine, the penetration power refers to the voltage (kV) applied to the X-ray machine. For radioactive source, the penetration power depends on its source strength and also the energy of the source. A general rule is for light and thin materials such as rubber, wood, plastic, etc., low kV X-ray machines are suitable to use. On the other hand, for thick and dense materials, for instance, steel, concrete, etc., high kV X-ray machines or radioactive source are needed for the inspection.

Although the technique is good and reliable, yet, this technique has some limitations. One of the major limitations is to have the accessibility from both sides of the specimen, which means that the source and the detector must be placed on the opposite side. Thus, this technique is less useful when accessibility is limited. Hence an improved technique using radiography method with only accessibility from one side is necessary. Another constraint of radiography technique is that the radiographer must always be aware and alert of the hazards while operating the machines. Efforts must be taken to minimise the over exposure to the radiation workers as well as the public. Over exposure and accident involving radioactive source will lead to declaration of emergency situation and dangerous to human bodies.

1.3 Motivation

In industrial radiography, the images are the important output to the radiograph interpreters. Hence, sharp images are important to them. A sharp image in radiography means good image quality. However, the quality of the images may sometimes get degraded. The degradation of images may be due to many factors and which the main factor will be the contribution of the scattering radiation. The scattering radiation may result in the reduction of the flaw sensitivity.

Figure 1.1 shows the process of attenuation in a sample where I_0 is the intensity from the source. Primary radiation I_p is the radiation from the source not attenuated in the sample and it is recorded by the detector. However, the amount of I_p is less than I_0 after passing through the material since part of I_0 will be attenuated in the sample. In the sample, the radiation will undergo various processes of interactions and producing the secondary radiation which consists of scattered radiation I_s and Bremstrahlung radiation.

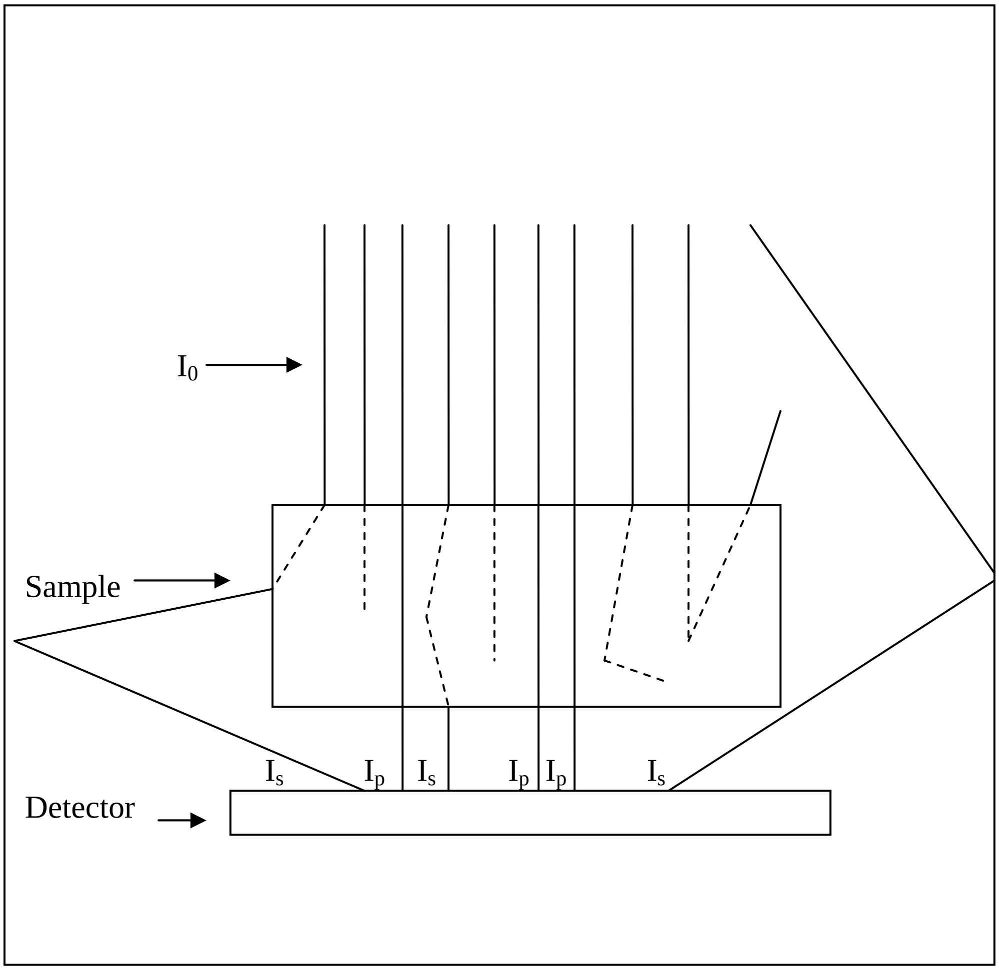

Figure 1.1 Attenuation of radiations in the sample.

There are three types of scattering that occur in radiography namely internal scattering, side scattering and back scattering. Internal scattering is scattering that occurs inside the material being radiographed. The scattering processes involved are for example Rayleigh scattering or elastic scattering and Compton scattering or inelastic scattering. This internal scattering process cannot be reduced and eliminated. Side scattering is the scattering from walls, or any other objects in the vicinity of the specimens or from portions of specimen, that are in the path of the primary radiation [1]. As a result, blurring of the edge of the image will be seen on the radiograph [1].

Backscatter radiation is scattering radiation that originates from material located beneath the film such as the floor, tabletop or film cassette. This type of scattering radiation will reduce the sharpness of the image [1]. The scattering radiation is produced from the interaction of the radiation with the nearby material which also includes air that irradiated by the primary beam. It is also important to note that the secondary scattered radiation will be produced by the specimen.

One of the important parameters in the determination of the attenuation constant is the scattering cross section. Most of the calculation on the cross section is for medical uses [2] and very few for industrial applications. This is due to its application in cancer treatment and nuclear medicine involving ionising radiation to the human cells which in this case must be done with high accuracy to prevent any further biological damages [3,4]. In the industrial applications, scattered radiation namely Compton scattering is important [3]. There are many applications using the concept of Compton scattering such as using Compton scattering of gamma-rays as a surface inspection technique for NDT [5]. Anjos [5] in his paper concluded that Compton scattering can be used for inspection of surfaces to detect defects such as cracks, holes and voids using his system with dimension up to 1.6 mm.

In most of the literature, Caesium-137 (Cs-137) is used as the source [6] which has lines at low energies. However in NDT applications the radioisotopes used are of high energy such as Iridium-192 (Ir-192) and Cobalt-60 (Co-60). However there is not much research on the cross section using Iridium-192.

There are two-fold objectives in this work. The focus of this work is to measure the attenuation coefficients of γ radiation from Iridium-192 source for carbon steel plates. Before measuring the attenuation coefficients, the understanding of the internal scattering process that is the information on cross section is important. Hence, in the first objective, effort is given to the calculation of cross section. This research gives values of the cross section of certain elements which will take into consideration the electron binding effects in the material and not solely rely on the bare Klein-Nishina formula. The improved values on the cross section would refine on the values on attenuation coefficients for materials used in industrial applications.

There are various types of steel namely mild steel, stainless steel, carbon steel etc. Carbon steel is one of the main components that made up the main components in pipeline in various industries which used mainly to transport substances such as liquids and gases. Since the author is working in NDT for oil and gas industry, hence we choose carbon steel as our sample because it is very widely used in the oil and gas industry as well as petrochemical plant. Thus the second objective is to measure and calculate the attenuation coefficient of carbon steel utilizing the cross section from the first objective.

1.4 Organization of the Thesis

There are five chapters in this thesis. Chapter 1 is the introduction to the research and followed by Chapter 2. Chapter 2 is on literature survey. The literature survey for this chapter includes the discussion on scattering processes and attenuation coefficient. Chapter 3 delves on the scattering cross section. The cross section is mainly on inelastic scattering i.e. the Compton scattering where the method of calculating the cross section is discussed. Chapter 4 is on the subject of attenuation coefficient. In this chapter, the experiments done to obtain the attenuation coefficients are discussed. The results and the analyses of the data of the experiment are also discussed in this chapter.

The last chapter namely Chapter 5 is the conclusion and suggestions for further study. In this last chapter, we will give the overall conclusion of the research work and some further work that could be done to improve the calculation on cross section particularly on incoherent scattering cross section.