DENSITY PROFILE COMPARISON OF DIFFERENT BUILD-UP USING GAMMA TRANSMISSION

Mohd Fitri Abdul Rahman[1], Hanafi Ithnin[1], Nurul Huda Azahar[2], Lahasen@ Normanshah Dahing[1], Airwan Affandi Mahmod[1], Hearie Hasan[1] & Nurliyana Abdullah[1]

[1]*Malaysian Nuclear Agency, Bangi, 43000, Kajang, Selangor.*
[2]*Politeknik Tun Syed Nasir Syed Ismail, Hub Pendidikan Tinggi Pagoh, KM1, Jln Panchor, Panchor, 84600 Pagoh, Johor.*
e-mail: fitri@nm.gov.my

ABSTRACT

Utilizing gamma radiation, a specialized pipe scanning apparatus was employed to detect anomalies within piping systems, showcasing its remarkable ability to effortlessly permeate metals and steel. Nevertheless, the task of identifying constituent materials within piping systems becomes intricate in the presence of multiple samples. This state-of-the-art pipe scanning technology serves the purpose of non-destructively examining pipes and finds extensive application in industries like oil and gas, manufacturing, and infrastructure. This study primarily focuses on a comparative analysis between empirical experimentation and computational modelling. The investigation underscores the pipe scanner's precision in recognizing and characterizing anomalies within simulated samples. The outcomes of this research bear significant relevance to industries reliant on pipe systems, signifying advancements in inspection methodologies.

ABSTRAK

Menggunakan sinaran gamma, radas pengimbasan paip khusus digunakan untuk mengesan anomali dalam sistem paip, mempamerkan keupayaan luar biasa untuk meresap logam dan keluli dengan mudah. Namun begitu, tugas mengenal pasti bahan konstituen dalam sistem perpaipan menjadi rumit dengan kehadiran berbilang sampel. Teknologi pengimbasan paip tercanggih ini berfungsi untuk memeriksa paip tanpa merosakkan dan menemui aplikasi yang meluas dalam industri seperti minyak dan gas, pembuatan dan infrastruktur. Kajian ini tertumpu terutamanya pada analisis perbandingan antara eksperimen empirikal dan pemodelan pengiraan. Siasatan menggariskan ketepatan pengimbas paip dalam mengenali dan mencirikan anomali dalam sampel simulasi. Hasil penyelidikan ini mempunyai perkaitan yang ketara kepada industri yang bergantung kepada sistem paip, yang menandakan kemajuan dalam metodologi pemeriksaan.

Keywords: gamma transmission, pipe scanning technology, inspection methodologies

INTRODUCTION

Gamma rays can be used for online investigations because they penetrate and pass through matter, such as steel pipe, and are attenuated to a degree directly proportional to the material density and thickness [1,2]. By measuring the relative attenuation of the transmitted gamma rays, accurate information can be inferred about the material that they have passed through. The technique works by irradiating the samples with gamma rays, which in this case is a pipe scanner. The amount of radiation that is transmitted through the samples is measured by a scalar ratemeter. The amount of radiation that is transmitted is inversely proportional to the density of the samples.

There are various systems and applications that have been developed using the gamma transmission technique to solve industrial problems [3-5]. In industrial pipelines, the build-up or scale deposit is among the major issues to be monitored inside the process pipe. The buildup factor is a correction factor that is used to account for the attenuation of the gamma rays by the material. The build-up factor is dependent on the energy of the gamma rays, the density of the material, and the thickness of the material [6]. The density profile is a plot of the density of a material as a function of depth. The density profile can be obtained by measuring the gamma transmission at different depths in the material.

The comparison of density profiles of different build-ups can be used to study the effects of the build-up factor on the accuracy of the density measurements. The comparison can also be used to develop more accurate build-up factors for different materials and gamma ray energies.

METHODOLOGY

Experimental Setup

This study involves laboratory experiments using two different pipe diameters with four build-up samples and simulation for the same pipe size and samples. The four samples are rectangular packed sand (1.6 g/cm^3), cylindrical water (1.0 g/cm^3), cylindrical oil (0.9 g/cm^3), and a random medicine sample (0.14 g/cm^3). The inner diameter of the smaller pipe is 10.3 cm, and the larger pipe is 25.5 cm, with both pipes having the same wall and insulator thickness. Figure 1 illustrates the setup for the pipe scanning experiment done in our lab. The gamma-ray-sealed source used was Caesium, Cs-137 with an energy of 662 keV, while detectors are Sodium Iodide, NaI scintillator-type detectors. Both the radioactive source and detector used were collimated using Lead, Pb collimator with a 0.5 cm circular aperture.

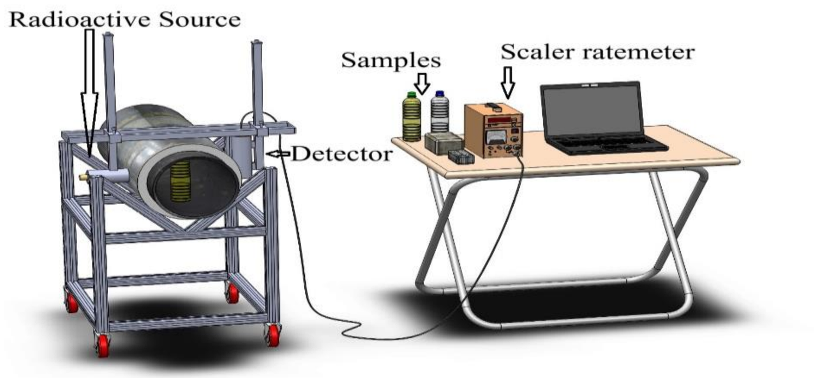

Figure 1. Schematic Diagram Experimental on Different Samples using Pipe Scanner

Before commencing the scanning procedure, it is imperative to conduct a stability test on the detector, cable and ratemeter. This step is essential to achieve the optimal high voltage for the NaI detector and to ensure that all equipment is in a satisfactory condition. Begin by identifying the zero-degree reference point on the pipe. Subsequently, create a measurement scale spanning 360 degrees along the pipeline diameter. For small pipelines, establish intervals of 30 degrees, while for larger pipelines, use intervals of 22.5 degrees. Prior to conducting the measurement process, record the air count both before and after the procedure. This step is crucial for assessing the stability of the measurement units throughout the scanning process and ensuring the instrument unit operates effectively. Next, carefully select and measure a representative section of the pipeline that is devoid of deposits and remains clean. This measurement will serve as the reference scan, denoted as Io (clean pipe), against which subsequent scans will be compared.

Insert the sample into the pipeline, as shown in Figure 2, and initiate measurements from the zero-degree position, progressing to 360 degrees. In this setup, the radiation source is positioned above the pipeline, while the detector is located beneath it. For smaller pipes, measurements are recorded at 30-degree intervals, and for larger pipes, measurements occur at 22.5-degree intervals. Each measurement is conducted for a duration of 8 seconds, and it is advisable to acquire at least three readings at each scanning point for accuracy and reliability.

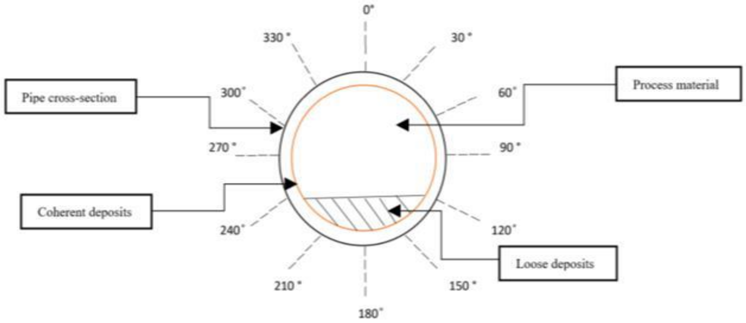

Figure 2 . Sample position inside the pipeline (left). the scanning orientation and the measurement points (right)

The transmitted radiation intensity, as a function of distance from the initial point, was recorded via a portable scaler/ratemeter/analyser-laptop computer system to facilitate data storage. After completing the scanning process, all the data was processed and analysed.

Simulation Setup

The simulation for the pipe scanning experiment was executed using the Particle and Heavy Ion Transport Code System (PHITS) [7]. As a general-purpose Monte Carlo particle transport simulation software, PHITS is used in many studies in the fields of accelerator technology, radiotherapy, space radiation, etc. In this study, the gamma-ray radiation and attenuation through the sample inside a pipe is simulated using PHITS. First, the 3D-geometrical model of the insulated pipe with each sample and detector was modelled. Figure 3 shows the PHITS pipe scanning cross-section modelled with four samples placed inside the pipe: (a) water, (b) oil, (c) sand and (d) medicine sample.

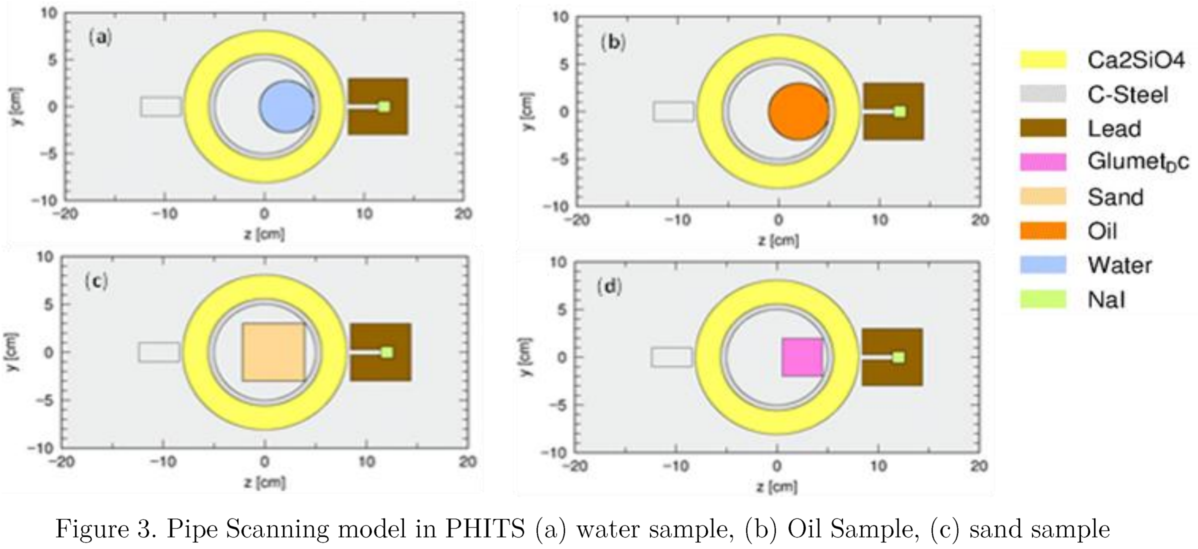

Figure 3. Pipe Scanning model in PHITS (a) water sample, (b) Oil Sample, (c) sand sample and (d) Glumet DC sample

The setup for the simulation study flows exactly as in the experimental work, where the scanning is done at different angles for all of the samples being studied using two different pipe diameters (10.16 cm and 25.4 cm). Figure 4 illustrates an example of gamma-ray tracking using PHITS at four different angles for a water sample inside the first pipe. The gamma-ray source positioned opposite of the detector and emitted the gamma ray through the pipe and sample. The attenuated value from the source is then tallied on the NaI detector cell using T-Deposit tally. The calculation was then repeated at different scanning angles and different samples.

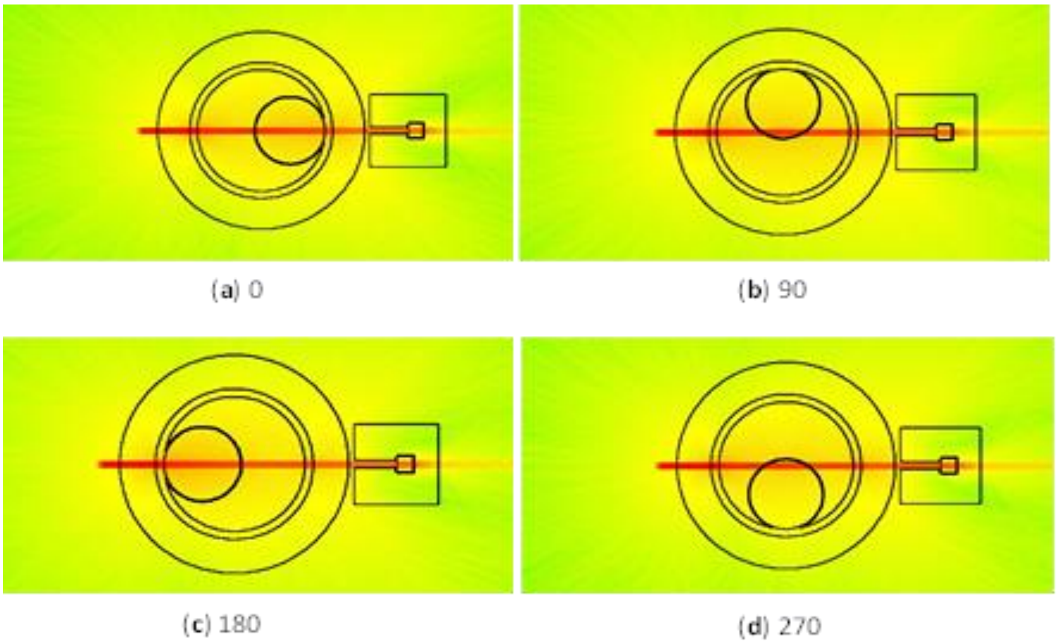

Figure 4. The example of gamma-ray tracking in the PHITS simulation at four different angles

RESULTS & DISCUSSION

Experimental

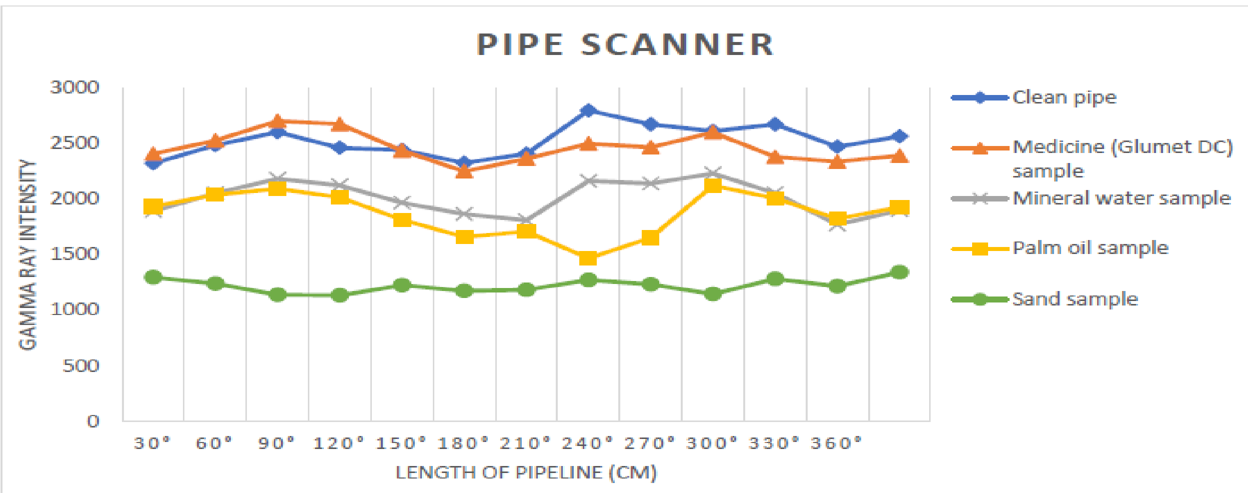

Figure 5 . Graph of gamma-ray intensity profile for small pipe

From the graph in figure 5, it shows the pattern of gamma-ray intensity of the samples. It shows that each sample responded to an almost similar pattern to gamma-ray, which passes through it. From the pattern of the gamma-ray intensity, it shows that the sand sample is very low-reading compared to other clean pipes or other samples. It's followed by palm oil and mineral water, with the highest reading observed for medicine, which is nearly identical to the clean pipe reading, Io. This is due to the gamma-ray absorption activity of the samples, which depends on the density of the material.

The graph also illustrates that varying the scanning angle results in the difference of count/reading measurement. Count/reading at the 0, 180, and 360-degree positions lower than 90 and 270-degree positions, except sand, which has an almost similar count/reading. This is because the position of sample inside the pipeline is at a bottom area (0, 180 and 360-degrees). The shape of the sample also influences the absorption of radiation. The more radiation reaches the area of the sample, the lower the reading.

Figure 6 illustrates the profile of gamma-ray intensity for the samples, revealing a similar pattern for each sample but varying gamma-ray counts or readings that pass through it. The graph also demonstrates that the sand sample exhibits a lower reading/count compared to the clean pipe Io, followed by palm oil, mineral water and the highest is medicine. This is due to the process of gamma-ray absorption activity by the samples where it depends on the density, the sharpness, and the location of the sample inside the pipeline. In terms of sample positioning, it is primarily situated at the bottom but predominantly within the side area, spanning from the 180-degree to the 270-degree section.

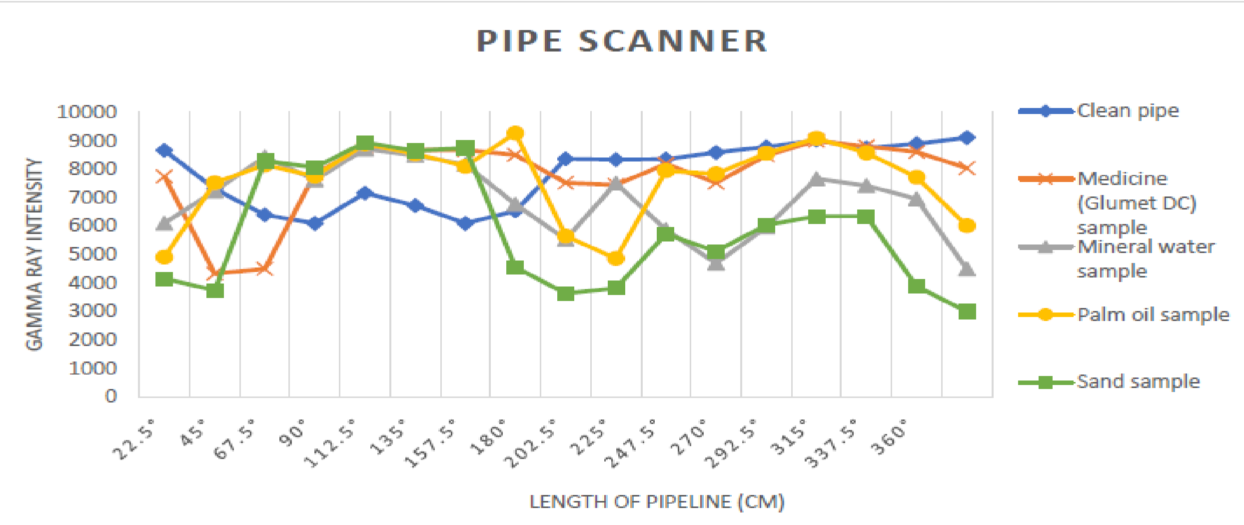

Figure 6. Graph of gamma-ray intensity profile for big pipe

However, the data for Io in the region between 45 degrees to 180 degrees appears anomalous. It should ideally form a straight-line graph with readings higher than those of the samples. Perhaps this happens during the scanning process, where the position of the detector and radiation are incorrect or the thickness of the pipe at this point is experiencing corrosion activity.

Simulation

Figure 7 displays graphs illustrating detector responses to gamma-ray attenuation from source to detector at different scanning angles. The results suggested that the attenuation for the different materials depends on their density, as demonstrated in Figure 7(a), where the detector response decreases as the material density increases. The shape also influenced the detector response count as the gamma-ray attenuation path inside the sample depends on that sample shape at different scanning angles. This can be seen on the plotted graph of the sand sample (rectangle) versus the oil and water sample (circle). In Figure 7(b) the graph shows that at several angular positions, the detector response counts are the same as a clean pipe. This is due to the sample's largest cross section is less than the radius of the large pipe; thus, the gamma rays are not passing through the samples at those angles.

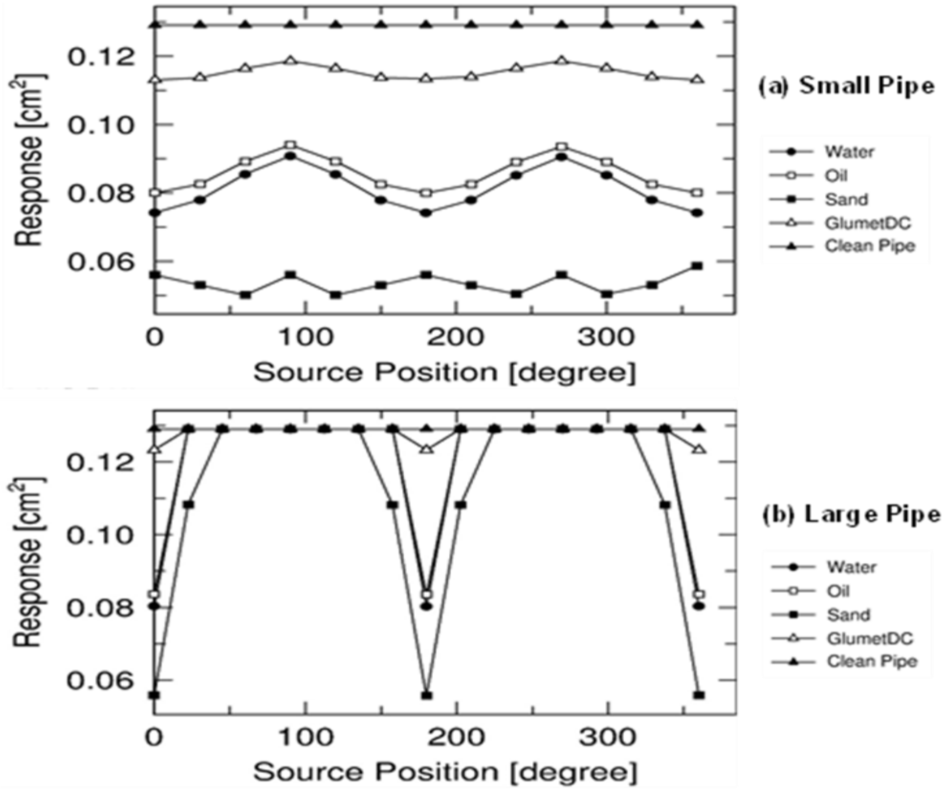

Figure 7. Graph of detector response at different scanning angel for (a) Small pipe and (b) Large pipe

CONCLUSION

The exploration of density profile disparities in different build-up materials through gamma transmission techniques has yielded significant findings and implications, underscoring the importance of this research in radiation-intensive applications and industries. Throughout our investigation, we have discerned that the choice of build-up materials plays a pivotal role in shaping the behavior of gamma radiation across various scenarios. Our comprehensive examination of density profiles in materials such as sand, water, oil, and GlumetDC has unveiled distinct attenuation and penetration characteristics. These insights are paramount for optimizing the precision and efficacy of radiation-based procedures.

The alignment between experimental results and simulations has generally revealed consistent findings, primarily attributed to the penetration behavior of gamma rays. However, it is important to note that certain experiments displayed some inaccuracies, largely stemming from variations in sample positioning compared to the simulations. Nevertheless, conducting simulations prior to any experimental work remains a crucial prerequisite.

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