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Image Reconstruction of Polypropylene (PP) with Rebars by Filtered Back Projection Algorithm using PHITS and MATLAB

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Abstract

The current research focuses on simulation of image reconstruction of polypropylene (PP) with rebars by filtered back projection algorithm using PHITS and MATLAB program. Linear attenuation coefficients (μ) and mass attenuation coefficients (μ_m) were investigated in the photon energies of 0.03 to 20 MeV. particle and heavy ion transport code system (PHITS) was used with gamma radiation narrow beam transmission technique. Simulation measurements were carried out by NaI (Tl) detector and Cs-137 source. Firstly, pure polypropylene block was carried out with PHITS simulation. Secondly, standard phantom of cylindrical polypropylene with 5 cm diameters of two holes was studied according to IAEA TECDOC series. Thirdly, the samples of polypropylene block containing one steel bar and two steel bars with different diameters were also tested. These phantoms were scanned with 6° intervals over 0 to 180° in PHITS simulation and measured with moving of center to center detector spacing of 0.5 cm, 1.0 cm and 1.5 cm, respectively. The most popular methods in image reconstruction is filtered back projection (FBP) algorithm. The results indicated that the images of the phantoms in image reconstruction were seen clearly at 0.5 cm distance of spacing. Performance improvements in MATLAB were investigated. It was found that spline and without filter were the best functions for the clearest image of polypropylene for both two holes, and one bar and two bars. Therefore, the obtained images indicated that FBP algorithm used in MATLAB can be substantial for various applications in the field of medicine and industry.

Keywords

Attenuation Coefficients, Filtered Back Projections, Image Reconstruction, Polypropylene

INTRODUCTION

Polypropylene is an essential plastics with thermal that contains cheap, light weight, good mechanical properties, and broad industrialized and applications. which require high energy radiation. Regarding on polymers, ionizing radiation will be used which introduces energy into materials to generate favourable changes and provides the proper doses. Gamma rays in irradiation of polymeric materials produce ionization and excitation [1].

High atomic number (z) elements such as barium, lead, and bismuth are used to attenuate gamma radiations. Polymers and plastics are frequently used in medical applications. Softness, insulation, elasticity, and low weight, polymers are widely used in a variety of industries. Polymers based on carbon, hydrogen, and oxygen are not flammable and their characteristics have a low weight, are less expensive, are more stable at high temperatures, and can be used on a large scale [2].

Tissue equivalent materials and radiation masks were used in the choice of best radiation shielding materials. In addition, most of the polymers contain high hydrogen content and they are effective for shielding against gamma rays. Thus, polymers are considered as better shielding materials against exposure of personnel to gamma radiation [3].

Monte Carlo (MC) method simulates the interaction of radiation with matter. One of the MC programs is PHITS [4]. PHITS means Particle and Heavy Ion Transport code System and this code is a multi-purpose tool for simulating particles transportation phenomena developed by JAEA (Japan Atomic Energy Agency) and several other institutes. PHITS are used in many studies such as accelerator and detector design, particle therapy, and cosmic radiation and so on. photon interactions in polypropylene material are simulated by PHITS code in nuclear interactions and atomic data libraries [2]

Computed tomography (CT) is used in medical diagnosis and in specialized X-ray equipment. Each cross-sectional image of the imaged person is used for various therapeutic and diagnostic purposes. CT is an important tool to examine the interior features of the specimen and it is important to obtain high quality images [1]

Tomography is used for diagnostic purposes not only in medicine but also in the fields of industry, biology and engineering. An object is reconstructed by its projections. Computed tomography (CT) refers to reconstruction of physical parameter of specimen from gamma rays [6].

Image quality and radiation dose can influence image reconstruction. Noise images in reconstructing for a given radiation dose can be reduced by enhancing of image quality. CT images can be achieved by using FBP in most circumstances [7].

The aim of this research is to reconstruct images of polypropylene (PP) by filtered back projection (FBP)

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algorithm using PHITS and MATLAB program.

MATERIALS AND METHODS

Polypropylene and its Specifications

Physical, chemical, mechanical, thermal, and electrical properties are not found in any other plastic material but they are found in polypropylene (PP). Superior working temperature and tensile strength are seen in polypropylene. The densities are varying from 0.855 to 0.940 g/cm³ [8].

Chemical formula, density and atomic compositions of polypropylene sample were shown in Table 1 [2], [9]. These values were used in the input files of PHITS simulation.

Table 1. Chemical formula, density and atomic compositions of polypropylene sample

Polymer material	Chemical formula	Density (g/cm³)	Atomic Compositions (%)
Polypropylene (PP)	$(C_3H_6)_n$	0.855 - 0.94	C 85.62 H 14.38

PHITS Simulation Model

Photon attenuation coefficients of proposed polypropylene are investigated with gamma narrow beam geometry. A pure polypropylene block sample with thickness of 22 cm × 22 cm × 22 cm in the energy range of 0.03 to 20 MeV was used as a shield and placed between source and detector. Gamma source is defined as disk source with 2.54 cm diameter and the detector in this simulation is a NaI(Tl) scintillation detector with 2.54 cm diameter. In PHITS simulation, "t-track" tally was used [5]. Fig. 1 showed PHITS simulation model of source, polypropylene and detector.

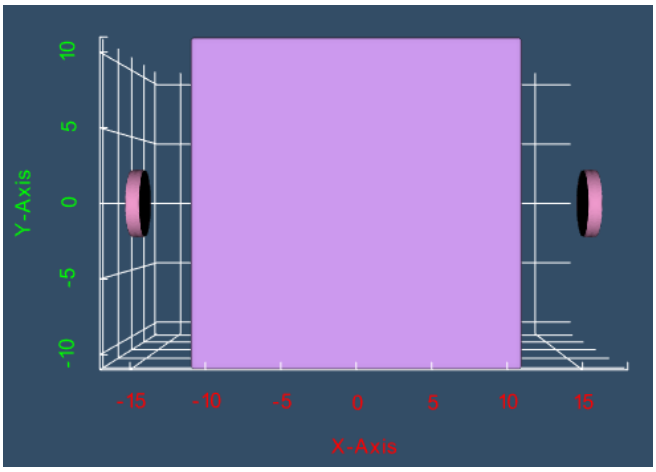

Figure 1. PHITS Simulation Model of source (left), polypropylene (middle) and detector (right) designed by PHITS code

Linear attenuation coefficients for Polypropylene

Linear and mass attenuation coefficients of polypropylene were calculated from PHITS simulation [10]. When a gamma-ray incidents a target object, the intensity of the ray will be attenuated by the Beer-Lambert's law [11].

$$I = I_o e^{-\mu t} \qquad (1)$$

Where I_0 is the initial intensity and I is the attenuated gamma ray intensities. μ (cm^{-1}) is the linear attenuation coefficient. t (cm) is the object thickness, Rearranging equation (1) and taking the logarithm of both sides results

$$\mu = \frac{\ln(\frac{I_o}{I})}{t} \qquad (2)$$

By dividing the linear absorption coefficient by the material density (g/cm³), which is known as the mass absorption coefficient (μ_m), the relationship between radiation and material density is made clear [2].

$$\frac{\mu}{\rho} = \frac{\ln(\frac{I_o}{I})}{\rho\, t} \qquad (3)$$

Filtered Back Projection (FBP) Algorithm

Filtered Back Projection (FBP) algorithm can be considered as a useful and effective reconstruction method The FBP algorithm is often referred as the convolution method using a one-dimensional integral equation for the reconstruction of a two-dimensional image. This method is the most popular reconstruction algorithm used at present in CT application [12]. The filtered back projection algorithm is used to reconstruct an object from its projections. A simple back projection causes blurring of the reconstructed object. To overcome this effect the projections is filtered using a high pass filter [7]. After applying the computer simulation of FBP on the image, the performance of algorithm and the quality of the image will be dependent on many considerations such as image size, number of projections and theta incremental [13].

Image Reconstruction

Image reconstruction has major effects on image quality and therefore on radiation dose. For a given radiation dose, it is preferable to reconstruct minimal noisy images without disturbing image accuracy and spatial resolution. Reconstructions that enhance image quality can reduce radiation dose, since lower dose can be used to reconstruct the same quality images. It is important to investigate the reconstruction of CT images, because CT imaging is widely used in various areas for treatment and diagnostics due to its ability to image the anatomical details. Also, advantages such as high spatial resolution and slice selection in any direction make CT imaging preferable. In addition, as it can be concluded from the present researches, high diagnostic quality CT images can be achieved by using FBP in most circumstances [14].

MATLAB Simulation

In this paper, a method of image reconstruction for concrete block has been presented and the performance of FBP algorithm has been improved. The MATLAB package was used as a tool in performing the programming of the proposed reconstruction process. When acquiring the data from the DAS obtained by parallel beam geometry of scanning by using MATLAB functions for image

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reconstructions [1]. The MATLAB program is extensively used in engineering and scientific circles for numeric intensive computing. There are many toolboxes available, the DSP toolbox & others in areas of optimization, spline, control and estimation, and system identification. There are some useful functions in the DSP toolbox for 2-dimensional signal processing: 2-D DFT's, convolution, correlation, and graphing. Separable and non separable processing is conveniently described in terms of matrices. Also many topics in image enhancement and restoration are conveniently described in terms of matrices. PC-MATLAB is a very convenient tool for processing small images or blocks, 64 × 64 often being an upper limit for processing, although larger blocks can be imported and displayed. In spite of these restrictions, it is possible to display and process full size 600 × 800 images using PC MATLAB and a graphics processor. The signal processor adds the possibility of accelerating numeric intensive operations by a factor of 10 to 40 [15].

RESULTS AND DISCUSSION

Calculated values of linear attenuation coefficient (μ) and mass attenuation coefficient (μm) of pure polypropylene block

Values of linear and mass attenuation coefficients of polypropylene block with thickness of 22 cm × 22 cm × 22 cm are calculated by using the equations (2) and (3). Calculated values of linear and mass attenuation coefficients for polypropylene (PP) block over the energy range of 0.03 to 20 MeV including 0.662 MeV is shown in Table 2. From this table, μ decreases with increasing of the photon energy over that energy range. Fig. 2 shows mass attenuation coefficient versus incident photon energy of polypropylene for interactions from X-Com data base. Fig. 3 shows linear attenuation coefficient as a functions of photon energy. It was found that the variation of linear attenuation coefficients is similar to mass attenuation coefficients and the values of linear attenuation coefficient decreased over the energy range of 0.03 to 20 MeV.

Calculated values of linear and mass attenuation coefficients for pure polypropylene block (PP) were presented in Table 2. The comparison of calculated values and X-Com data base of mass attenuation coefficients for polypropylene block over gamma energy ranging from 0.03 MeV to 20 MeV including 0.662 MeV have been shown in Table 3. From this table, μ_m decreases with the increasing of photon energy and the calculated values of μ_m and X-Com values are in good agreement across most energies but only each points have a certain differences.

The variation graph for calculated mass attenuation coefficient values and X-Com values of pure polypropylene block were presented by fig. 4. It was found that mass attenuation graph decreased with increasing the incident photon energy ranging from 0.03 MeV to 20 MeV. Mass attenuation coefficient values were calculated by dividing of linear attenuation coefficient values with material density.

Table 2. Calculated values of linear and mass attenuation coefficients for pure polypropylene block (PP)

Photon Energy (MeV)	Calculated values of linear attenuation coefficient (cm^{-1})	Calculated values of mass attenuation coefficient (cm^2/g)
0.0300	0.2275	0.2500
0.0400	0.1783	0.1960
0.0500	0.1692	0.1860
0.0600	0.1638	0.1800
0.0800	0.1510	0.1660
0.1000	0.1419	0.1560
0.1500	0.1246	0.1370
0.2000	0.1137	0.1250
0.3000	0.1001	0.1100
0.4000	0.0910	0.1000
0.5000	0.0819	0.0900
0.6000	0.0754	0.0829
0.6620	0.0692	0.0760
0.8000	0.0655	0.0720
1.0000	0.0582	0.0640
1.2500	0/0524	0.0576
1.5000	0.0482	0.0530
2.0000	0.0409	0.0450
3.0000	0.0336	0.0370
4.0000	0.0254	0/0280
5.0000	0.0236	0.0260
6.0000	0.0227	0/0250
8.0000	0.0182	0.0200
10.0000	0.0172	0.0190
15.0000	0.0113	0.0125
20.0000	0.0091	0.0100

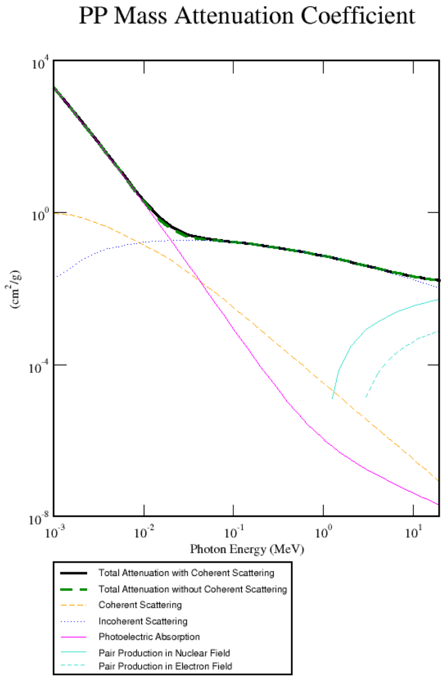

Figure 2. Mass attenuation coefficient Vs incident photon energy of polypropylene for total and partial interactions from X-Com data base

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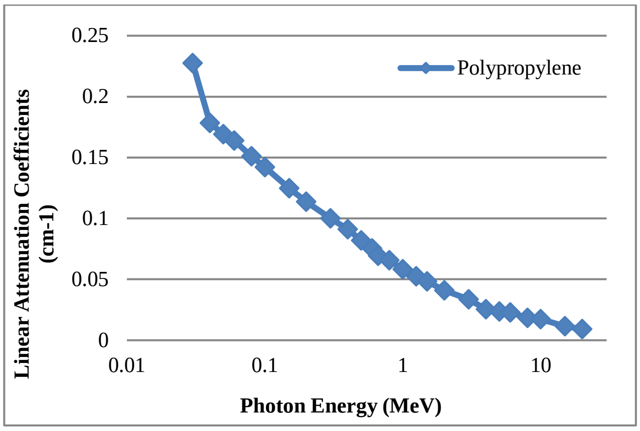

Figure 3. Calculated values of linear attenuation coefficient of polypropylene block

Table 3. Comparison of calculated values and X-Com Data Base of mass attenuation coefficients for pure polypropylene block (PP)

Photon Energy (MeV)	Calculated values of mass attenuation coefficient (cm^2/g)	X-Com Data Base	Relative Error (%) (~ 11%)
0.0300	0.2500	0.2707	7.6468
0.0400	0.1960	0.2200	10.9090
0.0500	0.1860	0.2080	10.5769
0.0600	0.1800	0/1970	8.6294
0.0800	0.1660	0.1823	8.9413
0.1000	0.1560	0.1710	9.2495
0.1500	0.1370	0.1534	10.6910
0.2000	0.1250	0.1400	10.7142
0.3000	0.1100	0.1217	9.6138
0.4000	0.1000	0.1090	8.2568
0.5000	0.0900	0.0994	9.4567
0.6000	0.0829	0.0881	5.9023
0.6620	0.0760	0.0850	10.5882
0.8000	0.0720	0.0808	10.8910
1.0000	0.0640	0.0710	9.8591
1.2500	0.0576	0.0650	10.9230
1.5000	0.0530	0.0591	10.3214
2.0000	0.0450	0.0500	10.0000
3.0000	0.0370	0.0405	8.6419
4.0000	0/0280	0.0310	9.6774
5.0000	0.0260	0/0290	10.3448
6.0000	0/0250	0/0275	9.0909
8.0000	0.0200	0.0220	9.0909
10.0000	0.0190	0.0210	9.5238
15.0000	0.0125	0.0140	10.7142
20.0000	0.0100	0.0110	9.0909

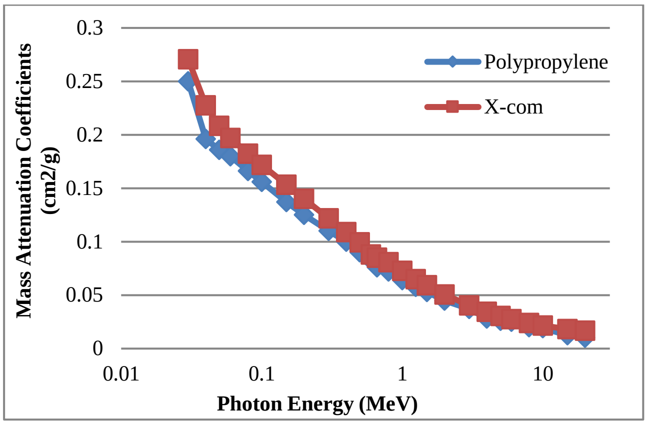

Figure 4. Comparison of calculated mass attenuation coefficient (cm^2/g) values and X-Com data base for polypropylene block

After the comparison of calculated mass attenuation coefficient (cm^2/g) values and X-Com data base for pure polypropylene block had been conducted, IAEA typical standard phantom, so called polypropylene (PP) cylinder, was also studied according to IAEA TECDOC series in the research work. The phantom is composed of solid polypropylene with 40 cm diameter containing two 5 cm diameter holes. The object was made of solid polypropylene. It has a density of from 0.855 to 0.940 g/cm^3 and has two holes inside it [16].

Scanning Procedure of polypropylene cylinder

In PHITS simulation, 0.662 MeV gamma photon energy as a gamma source was used to acquire sinogram data and NaI(Tl) detector was also used. Solid polypropylene containing 40 cm diameter with two 5 cm diameter holes was placed between source and detector. One first hole location of the cylinder was at the center of the cylinder and the second hole location was at 0.75 cm from the center of the cylinder to the right along its longitudinal axis [17]. The whole cylinder was scanned with various degrees from 0 to 180 degree at 6 degree intervals. At 0 degree condition, the cylinder was scanned with gamma source and detected with NaI detector to cover all the dimension of the sample. Then the sample was rotated about 6 degree intervals until 180 degree. After the sample was scanned, data were collected from the simulation and intensities were obtained. From the obtained data of the simulation, linear attenuation coefficients were calculated by the attenuation equation. The calculated data was constructed into images using filtered back projections algorithm. Image reconstruction was performed by MATLAB program. The image of PHITS simulation model for two holes cylindrical polypropylene was presented in fig. 5.

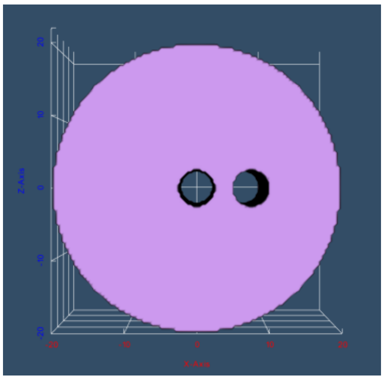

Figure 5. PHITS model for two holes cylindrical polypropylene

In this study, the cylindrical polypropylene sample was performed by filtered back projection algorithm using MATLAB program. The sample was scanned in translational mode at 0 degree to get the projections profiles. The step is every 1.5 cm distance of detector spacing. Each translational scan was conducted with 29 steps covering all the dimension of the sample. The sample is rotated 6 degree intervals until 180 degree and proceeded translational scan to obtain the data. It was carried out scanning sample again in every degree until all the 31 projections data were obtained. Fig. 6 showed the sinogram of the input image of two holes polypropylene.

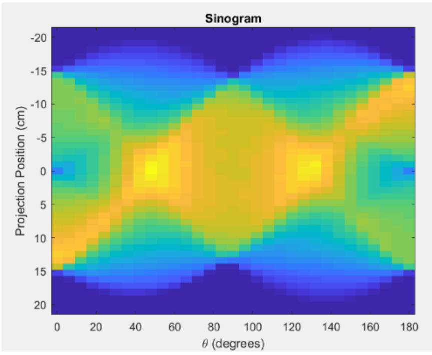

Figure 6. Sinogram of two holes polypropylene (1.5 cm detector spacing)

The above diagram at theta in range of 0 to 180 degree with 6 degree interval, the effect of interval indicates about the quality of the image. In this case, the detectors will count the gamma-ray at the same manner in each projection. In FBP algorithm, there are five input parameters such as angles, steps, interpolations, filters and frequency compression which values can be adjusted. Various interpolations and various filters containing without filter among the input parameters were tested to obtain the clear images. In this study, spline interpolation and no filter are presented for two holes polypropylene in image reconstruction using MATLAB. Fig. 7 showed the reconstructed image of two holes cylindrical polypropylene for the distance of 1.5 cm spacing between two detectors.

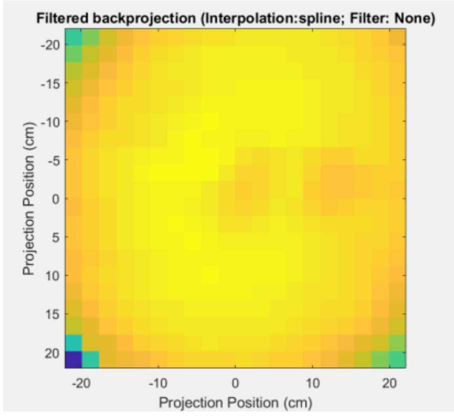

Figure 7. Reconstructed image of two holes polypropylene (1.5 cm detector spacing)

Then the sample was continued to test with every steps of 1.0 cm distance of detector spacing for two holes. Each translational scan was conducted with 41 steps covering all the object dimension in every degree. Fig. 8 showed the sinogram of the input image of two holes polypropylene.

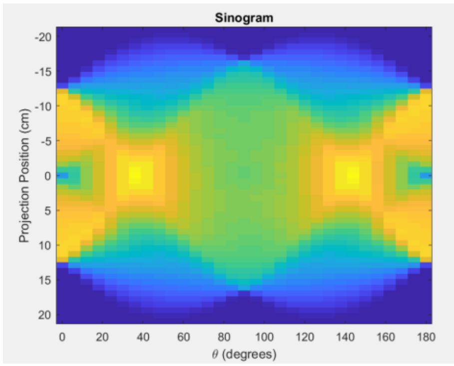

Figure 8. Sinogram of two holes polypropylene (1.0 cm detector spacing)

In this study, spline interpolation and without filter were presented for two holes polypropylene in image reconstruction using MATLAB. Fig. 9 showed the reconstructed image of two holes cylindrical polypropylene for the distance of 1.0 cm spacing between two detectors.

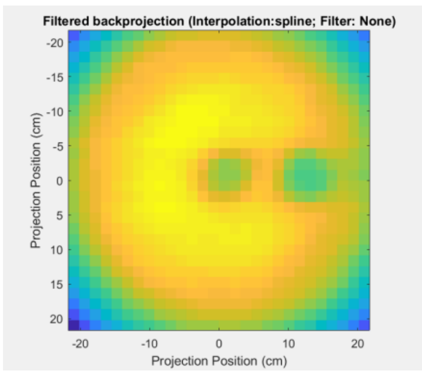

Figure 9. Reconstructed image of two holes polypropylene (1.0 cm detector spacing)

Then the sample was continued to test with every steps of

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0.5 cm distance for two holes. Each translational scan was conducted with 81 steps covering all the object dimension in every degree. Fig. 10 showed the sinogram of the input image of two holes polypropylene in MATLAB.

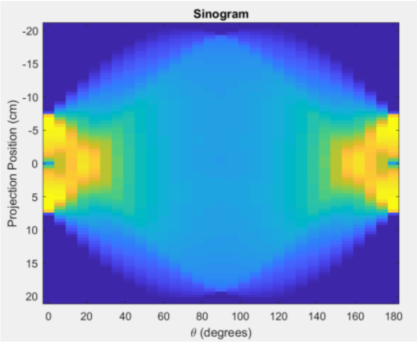

Figure 10. Sinogram of two holes polypropylene (0.5 cm detector spacing)

In this study, spline interpolation and without filter were presented for two holes polypropylene in image reconstruction using MATLAB. Fig. 11 showed the reconstructed image of two holes cylindrical polypropylene for the distance of 1.0 cm spacing between two detectors.

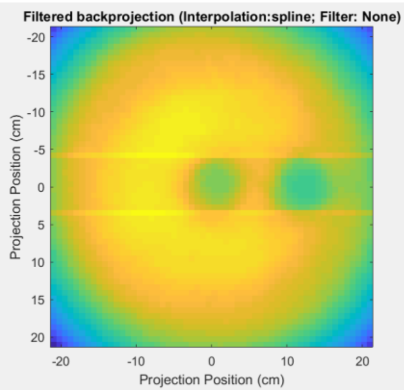

Figure 11. Reconstructed image of two holes polypropylene (0.5 cm detector spacing)

The reconstructed images of two holes polypropylene at 1.5 cm, 1.0 and 0.5 cm distances of detector spacing were carried out by MATLAB program using FBP algorithm. It was concluded that the reconstructed image of the sample at 0.5 cm detector spacing is the clearest image in this research work.

In order to validate PHITS simulation and MATLAB program, polypropylene block with one bar and two bars had also been tested. The projection data were obtained from PHITS simulation. The obtained projection data was constructed into image using FBP algorithm. Then image reconstruction was constructed by MATLAB program. The performance of PHITS and MATLAB program of polypropylene block with one bar and two bars were presented below.

Scanning of polypropylene block with one steel bar

Dimension of polypropylene block with 22 cm × 22 cm × 22 cm containing one steel bar was tested in PHITS simulation. Source to detector distance was 34 cm. To obtain the data for the sample block, the measured source was 0.662 MeV energy of Cs-137 gamma source and the considered detector was NaI crystal detector. The steel bar with 5 cm diameter in the vertical direction was placed at 4 cm from the center of the block to the right along the longitudinal axis [17]. The block sample was scanned with source and detector and computed linear attenuation coefficients values from the output results of PHITS. The projection data was constructed into the image using FBP algorithm. PHITS model of one bar polypropylene at 0 degree and 48 degree were presented in fig. 12 and 13. Image reconstruction was performed from the computed values of linear attenuation coefficients using MATLAB. The sinogram of one bar polypropylene in MATLAB was shown in fig. 14.

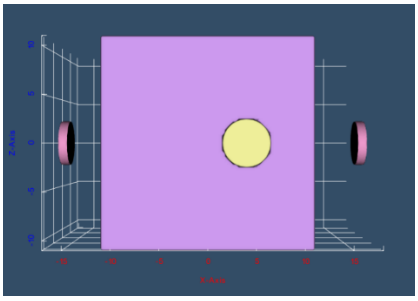

Figure 12. PHITS model for one bar polypropylene at 0 degree

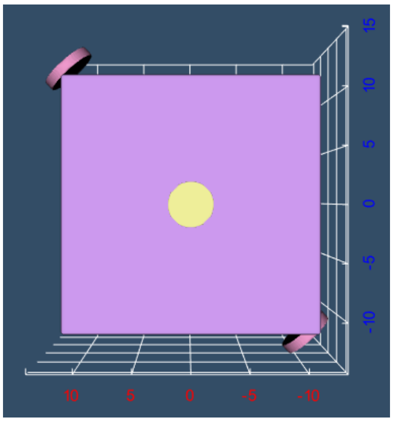

Figure 13. PHITS model for one bar polypropylene at 48 degree

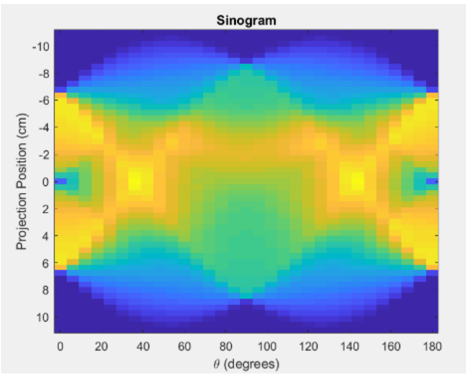

Figure 14. Sinogram for one bar polypropylene

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One bar polypropylene with various interpolation functions such as nearest, linear, pchip, v5cubic and spline was tested in MATLAB program. Among them, ‘spline’ was the best interpolation function. One bar polypropylene with various filter functions such as 'Shepp-Logan', 'Ram-Lak', 'Cosine', 'Hamming', 'Hann', as well as without filter was tested in MATLAB. Among them, it could be seen that ‘without’ filter was the best image. Reconstructed Image for one bar polypropylene using ‘spline’ interpolation and ‘without’ filter was shown in fig. 15. It was cleared that ‘spline’ interpolation and ‘without’ filter offered the clearest image for one bar polypropylene in image reconstruction.

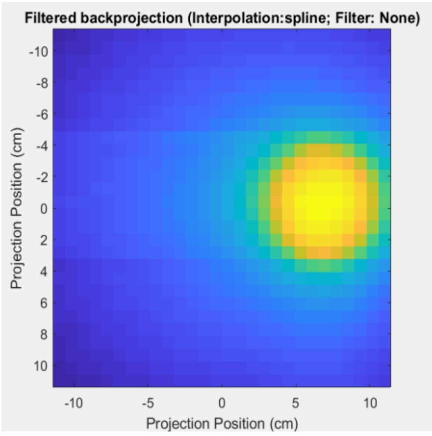

Figure 15. Reconstructed image for one bar polypropylene

Scanning of polypropylene block with two steel bars

Dimension of polypropylene block with 22 cm × 22 cm × 22 cm containing two steel bars was tested in PHITS simulation. Cs-137 gamma source and NaI(Tl) detector were used to obtain the data for the sample block. The two steel bars with 2.5 cm diameter and 5 cm diameter were placed at 4 cm distance each from the center of the block to the left and then from the center to the right along the longitudinal axis [17]. The block sample was scanned with source and detector and computed linear attenuation coefficients values from the output results of PHITS simulation. PHITS model of two bars polypropylene for 0 degree and 132 degree were presented in fig. 16 and fig. 17 and . Image reconstruction was performed from the computed values using MATLAB. The sinogram of two bars polypropylene in MATLAB was shown in fig. 18.

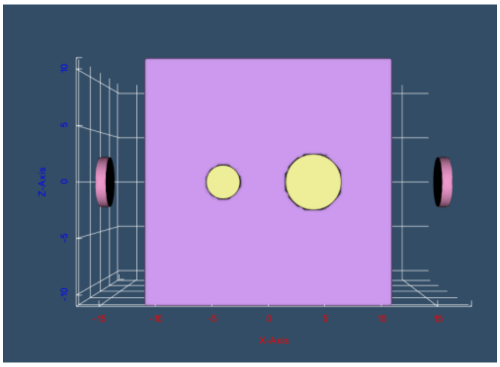

Figure 16. PHITS model for two bars polypropylene for 0 degree

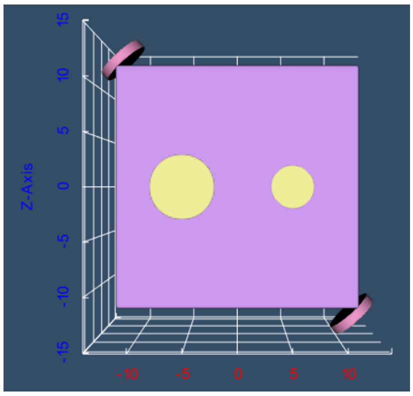

Figure 17. PHITS model for two bars polypropylene for 132 degree

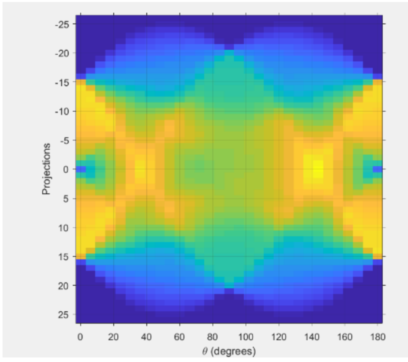

Figure 18. Sinogram for two bars polypropylene

Reconstructed Image for two bars polypropylene with ‘spline’ interpolation and ‘without’ filter was shown in fig. 19. It was observed that ‘spline’ interpolation and ‘without’ filter were the best functions for the clearest image of two bars polypropylene in image reconstruction.

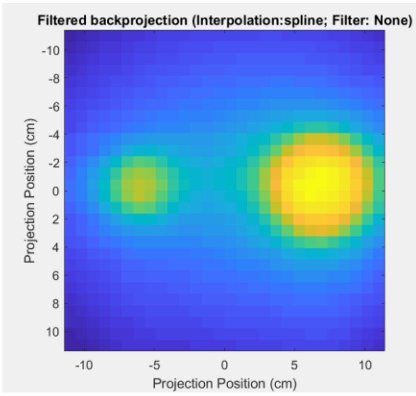

Figure 19. Reconstructed image for two bars polypropylene

CONCLUSION

In this study, pure polypropylene (PP) block sample has been simulated by PHITS code at incident photon energy ranging from 0.03 to 20 MeV including 0.662 MeV and the mass attenuation coefficient and linear attenuation coefficient of polypropylene block have been calculated by the equations. As a result, the gamma attenuation coefficient values of the sample decrease with the increasing gamma energy because gamma-ray attenuation coefficients depend on the incident gamma energy, material density and atomic composition of the materials. Then cylindrical polypropylene with two holes has also been studied by the PHITS code according to IAEA TECDOC series. Three detector spacing of 0.5 cm, 1.0 cm and 1.5 cm have been tested in the scanning of the sample from 0 to 180 degree with the step of 6 degree. It can be found that detector spacing of 0.5 cm is the best choice for the clearest image in image reconstruction using MATLAB by filtered back projection (FBP) algorithm. FBP algorithm has as a poweful reconstruction method for computed tomography (CT) images. Solid polypropylenes with one bar and two bars in the vertical direction have been performed in the PHITS simulation. In the one bar and two bars polypropylene, various interpolation functions and various filter functions have been used for image reconstruction using MATLAB program. It can be seen that, according to one bar and two bars polypropylene block images analysis, 'spline' interpolation and 'without' filter produced clearer resolution image. In contrast, the simulation method by the PHITS code has been observed appropriate method to study attenuation coefficients of polypropylene (PP) and overall, spline interpolation and without filter can be recommended to reconstruct images from projections in this research work.

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REFERENCES

[1] A. Adurafimihan Abiona* and A. Gabriel Osinkolu, **"**Gamma-irradiation induced property modification of Polypropylene," Materials Science and Electronic Division Centre for Energy Research and Development, Obafemi Awolowo University, Ile-Ife, Nigeria, 2010

[2] S.A. Abd EJ Azeem, "Assessment of linear, mass attenuation coefficients, and effective atomic numbers in some polymers for use as gamma-ray shields**,"** Physics Department, Faculty of Women for Arts, Science and Education, Ain Shams University, Cairo 11757, Egypt, Physics Department, College of Sciences and Humanities, Prince Sattam Bin Abdulaziz University, Al-Kharj 11942, Saudi Arabia, Arab J. Nucl. Sci. Appl., Vol. 56, 4, 9-16 2023

[3] Rajeshwari Mirji, Blaise Lobo, "Computation of the mass attenuation coefficient of polymeric materials at specific gamma photon energies," Radiation Physics and Chemistry, Department of Physics, Karnatak Science College, Karnatak University, Dharwad-580001, Karnataka, India, 2017

[4] E. E. Ermis, E. Pilicer,2 and C. Celiktas, "Comparison of the simulated gamma-ray attenuation coefficients with the real measurements," Ege University, Faculty of Science, Physics Department, 35100 Bornova, Izmir, Turkey, 2Uludag University, Faculty of Arts and Science, Physics Department, 16059 Gorukle, Bursa, Turkey, 2015

[5] C Sriwunkum1 and T Nutaro, "Study on gamma-ray shielding properties of lead tellurite glass systems using PHITS," Department of Physics, Faculty of Science, Ubon Ratchathani University, Ubon Ratchathani, 34190, Thailand, 2019

[6] Wibisono1,2 , Bayu Azmi1*, Sastra Kusuma Wijaya2 , Prawito2, and Firliyani Rahmatia Ningsih1, "Cross Sectional Imaging of Tree Stem Density Distribution using Gamma-Ray Tomography Technique." 1 Center for Isotopes and Radiation Application, BATAN, Jl. Lebak Bulus Raya No 49, Jakarta 12440, Indonesia 2 Department of Physics, Universitas Indonesia, Depok, 16424, Indonesia *E-mail: bayuazmi@batan.go.id, IOP Conf. Series: Journal of Physics: Conf. Series 1198 (2019) 022012

[7] Marwa. T. Al Hussani Mohammed H. Ali Al Hayani, "The Use of Filtered Back projection Algorithm for Reconstruction of tomographic Image," Electronics and Communication Eng. Dept, Al-Nahrain University Baghdad, Vol.17 No.2, 2014 pp.151-156, Iraq, 2014

[8] Ahmed M. El-Khatib 1, Thanaa I. Shalaby 2, Ali Antar 2 and Mohamed Elsafi, "Improving Gamma Ray Shielding Behaviors of Polypropylene Using PbO Nanoparticles. An Experimental Study," Physics Department, Faculty of Science, Alexandria University, Alexandria 21511, Egypt, elkhatib60@yahoo.com, 2 Department of Medical Biophysics, Medical Research Institute, Alexandria University, Alexandria 21561, Egypt; th_shalaby@yahoo.com(T.I.S.);newoten84@yahoo.com (A.A.) Correspondence: mohamedelsafi68@gmail.com, 2022

[9] https://ajnsa.journals.ekb.eg

[10] L Zhang, M C Jia, J J Gong, W M Xia**, "**Simulation of photon attenuation coefficients for high effective shielding material Lead-Boron Polyethylene," Department of Nuclear Science and Engineering Naval University of Engineering, Wuhan 430033, China, 2017

[11] Ripan Biswas a, Hossain Sahadath a, Abdus Sattar Mollah Md. Fazlul Huq, "Calculation of gamma-ray attenuation parameters for locally developed shielding material: Polyboron," Department of Nuclear Engineering, University of Dhaka, Dhaka 1000, Bangladesh b Bangladesh Atomic Energy Commission, Bangladesh, 2016

[12] Tugba Ozge Onur, "An application of filtered back projection method for computed tomography images,", Electrical-Electronics Engineering, B€ulent Ecevit University, 67100 Zonguldak, Turkey, 2021

[13] Bayu Azmi*, Wibisono, Darman, "Effect of Filter on Image Reconstruction using Filtered Back Projection Algorithm for Industrial Gamma-Ray Tomography Technique," Sugiharto Center for Isotopes and Radiation Application, National Nuclear Energy Agency (BATAN) Jl. Lebak Bulus Raya No. 49, Jakarta 12440, Indonesia, 2019

[14] C Sriwunkum1 and T Nutaro, "Study on gamma-ray shielding properties of lead tellurite glass systems using PHITS," Department of Physics, Faculty of Science, Ubon Ratchathani University, Ubon Ratchathani, 34190, Thailand, 2019

[15] Parul Goyal, "Image processing using Matlab**,"** Associate Professor**,** Department of Computer Science Engineering**,** Uttaranchal Institute of Technology, Dehradun.

[16] IAEA-TECDOC-1589, "Industrial Process Gamma Tomography," ISBN 978–920–0–104508–9, ISSN 1011–4289, IAEA, VIENNA, 2008

[17] HARRY E. MARTZ a , DANIEL J. SCHNEBERK a , G. PATRICK ROBERSON a & PAULO J.M. MONTEIRO a, "Computed Tomography Assessment of Reinforced Concrete," a Lawrence Livermore National Laboratory , Livermore, CA, 94550, USA b Civil Engineering Dept. , Univ. of California , Berkeley, CA, 94720, USA, Vol. 8-9, pp. 1035-1047, 2014.