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Study of Gamma Backscattering and Saturation Thickness Estimation for Granite and Glass

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ABSTRACT: *This paper presents the experimental work of finding values of saturation thickness of backscattering materials for gamma photons. This experimental work has been carried out using granite and glass to study the saturation thickness. The gamma backscattering is useful technique in determining density, thickness and composition of backscattering material. Gamma backscattering technique is a Non Destructive Testing (NDT) of material in which there is no direct contact with material under study and detector assembly. Up to certain thickness called saturation thickness the count rate of gamma photons backscattered by scattering material varies almost linearly with thickness of backscattering material. Using gamma backscattering, thickness of material can be determined by knowing count rate of backscattered gamma photons up to the saturation thickness. Also the density gauges operate above saturation thickness. Therefore study of saturation thickness is important. In this experimental work* ^{137}*Cs radioactive source and GSpec gamma spectroscopy system have been used. The spectral analysis was made using Spectrum Analysis and Analyzing Software (SAAS).*

KEYWORDS: *Backscattering,* ^{137}*Cs radioactive source, gamma photons, GSpec, thickness, SAAS.*

I. INTRODUCTION

In Non Destructive Testing (NDT) ultrasonic waves, X- rays, gamma rays, alpha radiations and beta radiations can be used as tools for investigation of sample. The ultrasonic method requires clean surfaces and temperature maintenance. The ultrasonic testing requires direct contact with the material of study. Hence using the ultrasonic method is very difficult in those cases where the materials under study are unclean, hot and rusted. The method of using nuclear radiations such as X- rays and gamma rays is useful in harsh conditions. In transmission measurements radioactive source and detector are located on opposite directions relative to the material of interest. This technique is not applicable if access to both sides of object is difficult. In such cases gamma backscattering technique is useful. The information regarding thickness and density of material can be obtained by gamma back scattering technique. This technique is based on detecting gamma photons backscattering from the interior of an object surface when gamma photons made to strike on the target material. In the gamma backscattering, the incident gamma photons are scattered backward compared to their incident direction. For fixed gamma ray energy, scattering angle, experimental environment and density of material of interest, the intensity of backscatter gamma photons depends on thickness of the material. The radiations usually employed in radiometric gauging and control devices are mainly x rays and gamma rays. Mathematical model of a gamma-ray backscattering gauge using ^{137}Cs (0.66 MeV) or ^{60}Co (1.17, 1.33 MeV) radioactive sources for probing surface rock and soil densities without the need of the boreholes required in transmission gauging have been developed [1]. In order to examine concrete walls in existing buildings, particularly for the presence, quantity, size, and position of steel reinforcing bars and also for voids Compton-scattering gamma ray single-scatter albedo probes have been introduced[2, 3]. On-stream and bulk analysis radiometric devices for probing iron and other ores on moving conveyor belts, using a variety of radiations including gamma rays and both fast and thermal neutrons have been described[4]. The number of backscattering photons increases according to the target thickness, eventually reaching saturation [5, 6]. The gamma backscattering method is very useful for estimating the thickness of hot objects, unclean and corroded surfaces when ultrasonic method fail to work. The gamma backscattering technique is useful in investigating historical objects [7]. The number of backscattering photons increases according to the thickness of target material [8]. The backscattered gamma beam will undergo attenuation in its way to the detector. The count rate in the detector is expected to change with thickness following the relation:

$$C = K1 \{1 – \exp [- (\mu+ \mu') t]\}$$

Where C is the count rate, K1 is a constant and μ and μ' are linear attenuation constant of incident and scattered gamma radiation beams and t is the thickness of the target material [9]. Up to certain thickness called saturation thickness, number of counts increases. The theory behind backscattering of gamma photons is complex in nature. The present work is intended to estimate values of saturation thickness of granite and glass practically irrespective of the theory.

II. EXPERIMENTAL WORK

The present experimental work employs gamma spectroscopy system, Gspec. The Gspec system consists NaI (Tl) crystal detector of size 2"x2" and MCA. GSPEC is a pc based Gamma Ray Spectroscopy system, which communicates with PC through USB port. Data Acquisition and Control is through PC based application software, SAAS (Spectrum Acquisition and Analysis Software). GSPEC has built in 14 Pin PMT base. The voltage divider and pulse processing circuitry is housed as front end electronics in GSPEC. This plug-in PMT on GSPEC makes is compatible with any NaI (Tl) detector with standard 14 Pin PMT. GSPEC is powered through USB port. NaI (Tl) detector PMT requires around 1000V DC. These voltages are generated by DC-DC convertors operating on 5V DC supply from USB port. Power supply for the instrument consists of +5V for digital circuits and +9 and -9V, for analog circuits. High Voltage supply is generated by programmable HV module. It can generate HV upto 1200V DC. The application of NaI (Tl) scintillators in gamma ray spectroscopy is based on their high efficiency for full energy absorption of gamma rays which permits the measurement of gamma ray intensity and energy. Even monochromatic gamma rays produce a complicated pulse height spectrum. The multi-channel analyzer displays the number of counts corresponding to a particular voltage on the vertical axis versus the amplitude of the voltage pulse on the horizontal axis. Each position on the horizontal axis is known as a channel. Calibration of multi-channel analyzer converts the channel number, which is proportional to the pulse amplitude into incident gamma energy. Energy calibration is done by selecting two or three energy peaks of known radio Isotopes. In the present work calibration was done using Co-60 (1.17 MeV, 1.333 MeV), and Cs-137 (0.662 MeV). Due to internal heating, external temperature variations and due to the internal drifts in detector, pulse processing electronics and HV supply circuit, there could be a small shift in the output of spectroscopy amplifier. In order to get the stability in the spectrum i.e. minimum variation in the channel number for given energy of incident gamma rays, it is necessary to get back to the originals setting of channel for a particular energy pulse input. This is normally done, by either adjusting the HV applied to the detector or by adjusting the gain of the spectroscopy amplifier. This stabilization can also be achieved by storing the energy calibration and applying the conversion factors at a fixed time interval. This is done automatically as the spectrum is being acquired. The Spectrum Stabilization Menu prompts user to enter the value of energy and also to enter the value of time interval. It is necessary to have the energy calibration prior to Spectrum Stabilization. The gamma spectrometry system was initially tested for resolution, linearity and stability characteristics to fix the best operating conditions by performing preliminary experiments. The resolution of the detector was found to be 6 - 10% for 662 KeV gamma rays at operating voltage 750V. Even in the absence of the radioactive source, background effects result from the active materials in the surroundings or in the scintillator and from electronic noise effects. Therefore in order to minimize the unwanted signals, walls and floors of the room and other scattering materials are kept as far as away from the spectrometer and a good stabilizer must be used to minimize electronic noise. The schematic arrangement for studying backscattering of gamma rays from samples is as shown in the Figure.(1). This arrangement provides good geometry setup. The Cs-137 radioactive source was kept in line with the Gamma spectrometer assembly at a distance of 4cm. The experimental work carried out using glass slabs of density 2.4 g/cm^{3}and granite slabs of density 2.7 g/cm^3 to estimate the saturation thickness by knowing the variation of count rate of backscattered gamma photons as a function of thickness of material under study. First the spectrum of gamma photons from ^{137}Cs radioactive source without backscattering sample was noted. The schematic of recorded spectrum is as shown in the Figure (2). For analysis of recorded spectrum, it is necessary to select the peak regions. This is done by selecting the Region of Interest (ROI). ROI will be selected between the start and stop channels as desired. From the recorded spectrum the backscattering peak has been identified and Region of Interest (ROI) was fixed for experimental work. The SAAS gives integral counts, background counts and background subtracted counts under ROI. For fixed experimental geometry the backscatter peak appears at around 184 keV when using the ^{137}Cs radioactive source. With the same experimental geometry the granite slab was placed directly in line with the ^{137}Cs radioactive source and detector assembly. The count rate under ROI was recorded. The backscattering sample thickness was increased by placing granite slabs one by one behind the previously placed granite slabs without disturbing the experimental geometry. The same procedure was repeated for glass slabs.

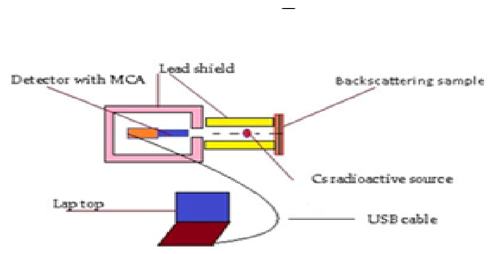

Figure1 Experimental arrangement

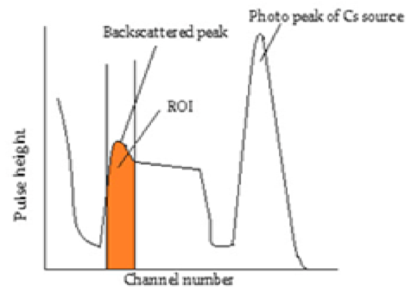

Figure2 Schematic of ^{137}Cs gamma spectrum.

III. RESULTS AND DISCUSSION

The low background gamma spectrum from ^{137}Cs radioactive source was eliminated by adjusting LLD at 6 and HV is kept at 750V throughout the entire experimental work. In order to avoid electronic noise generated by voltage supply, a good stabilizer was used. In order to avoid noise generated by internal heating of electronic circuitry inside the gamma spectroscopy system the experimental work was carried during night time. The thin scattering samples were used to avoid introduction of multiple scattering effect. The backscattered peak has been identified with at most care. The geometry of the experimental arrangement was kept undisturbed throughout the experimental work. Due to fixed experimental geometry and the good stabilization the centroid has fixed at nearly 184 keV. The TABLE I and TABLE II show the ROI analysis for granite and glass slabs respectively. From the TABLE I it was found that the count rate of gamma photons scattered from granite increases up to 1.2 cm steeply and then it increases slowly up to 2 cm. At 2.2cm the count rate reaches its saturation value. From the TABLE II it was found that the count rate of gamma photons scattered from glass increases up to 1.6cm steeply and then it increases slowly up to 2 cm. At 2.4cm the count rate reaches its saturation value.

Table I: ROI analysis for granite

Thickness(cm)	Net counts under ROI for 53 sec	Count rate (Counts/sec)
0	5158	97.3
0.8	7813	147.4
1.2	8519	160.7
1.6	8745	165
2.2	9165	173
2.4	9222	174
2.8	9282	175.1
3.2	9285	175.2
4	9282	175.1
5	9222	174

Table II: ROI analysis for glass

Thickness(cm)	Net counts under ROI for 53 sec	Count rate (Counts/sec)
0	5098	96.2
0.4	6901	130.2
0.8	9400	177.36
1.2	10706	202
1.6	11546	217.85
2.0	12296	232
2.4	13068	246.57
2.8	13266	250.3
3.2	13250	250
4.0	13228.8	249.6
4.8	13223	249.5
5.6	13181	248.7

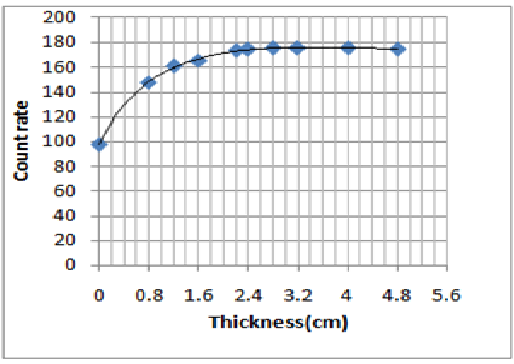

Figure3: Count rate versus thickness for granite

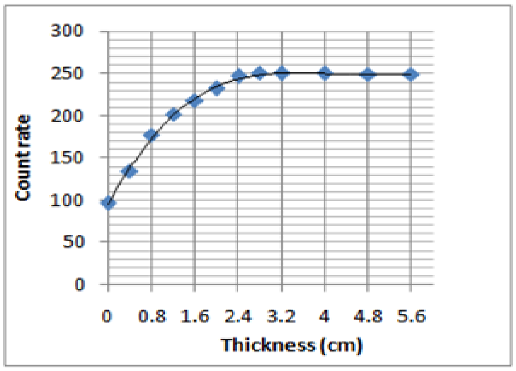

Figure4: Count rate versus thickness for glass.

IV. CONCLUSION

This experimental work concludes that the ^{137}Cs radioactive source is effective in the study of backscattering of gamma photons from scattering materials. The 662 keV gamma photons from the Cs radioactive source can be effectively backscattered from the granite and glass slabs. The experimental results confirmed that the backscattering gamma count rate varies nearly linear up to limited thickness of backscattering material called saturation thickness. Beyond saturation thickness the count rate was found almost constant. The little bit decrement in the count rate beyond the saturation thickness is due to effect of multiple scattering. The saturation thickness depends on density of scattering material. The saturation thickness measured for 662 keV gamma photons is greater for granite than that for the glass because of higher density of granite than glass. Thus this type of experimental work will help to estimate the density of materials. This type of experimental work also helps to measure thickness of material of interest by knowing saturation thickness of the material. The thickness less than saturation value the count rate varies nearly linear. From this knowledge the calibration curves can be drawn to estimate the thickness of backscattering material. This inexpensive and effective nondestructive testing can be used to study important structural properties like density, thickness and composition of metals, metal alloys and compounds.

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