Asian Journal of Chemistry Vol. 21, No. 10 (2009), S301-304

A Gamma Scattering Technique for Inspecting Density Variation

AMANDEEP SHARMA, M.P. SINGH, BHAJAN SINGH and B.S.SANDHU
Physics Department, Punjabi University, Patiala -147002, India
Tel : + 91 98728 09265, Fax : + 91 175 3046163, email : balvir@pbi.ac.in

Compton scattering, strongly depends on the electron density of the scattering medium (and in turn its mass density), is a viable tool for inspecting material. The aim of the present work is to investigate the feasibility of using gamma-ray scattering to inspect density variation in any object. A well collimated beam of 662 keV gamma-rays from 137Cs radioactive source has been used to extract the information of density variation for interior of sample by recording spectra with NaI(Tl) scintillation detector. The results confirm that experimental resolution for density variation in the inspected object is quite good.

Key Words: Compton scattering, Density variation, Non-destructive evaluation

INTRODUCTION

The inherent ability of Compton scattering can ascertain quantitative information of electron density of the target material. When the target is bombarded with high energy (above 100 keV to compete against photoelectric absorption) photons, ensuring that Compton scattering is the dominant mode of interaction, the measured scattering response will be proportional to the electron density of scattering point. The latter is of considerable value if changes in material composition are to be assessed non-invasively, such as in medical diagnostics, therapy, and in industry. The purpose of this study is to examine the potential of the use of Compton scattering to evaluate the density variation in inspected objects. In the present paper, a method is presented for flaw/inclusion detection using Compton scattering which relies on monitoring the intensity of radiation scattered from a particular voxel within the target material. Mullin *et al.*[1] have used this technique for detection of small collinear defects in aluminium blocks and laminated composite materials. For this study they used ^{60}Co source emitting photons with two distinct energies of 1.173 and 1.332 MeV at scattering angle of 90° with the help of HPGe detector. Hussein *et al.*[2] have used this method for inspecting concrete structures by using NaI(Tl) detector and ^{137}Cs radioactive source. Zhu *et al.*[3] have constructed in-line density measurement system based on X-ray Compton scattering for detection of density variation between the cogs of rings. The present work is a non-destructive testing of materials by using Compton scattering technique and thus will constitutes a valuable contribution to the literature.

EXPERIMENTAL SET-UP AND METHOD OF MEASUREMENTS

Fig. 1 shows experimental set-up used in the present measurements to observe incoherent scattered photon flux. A well collimated beam of 662 keV gamma-rays from

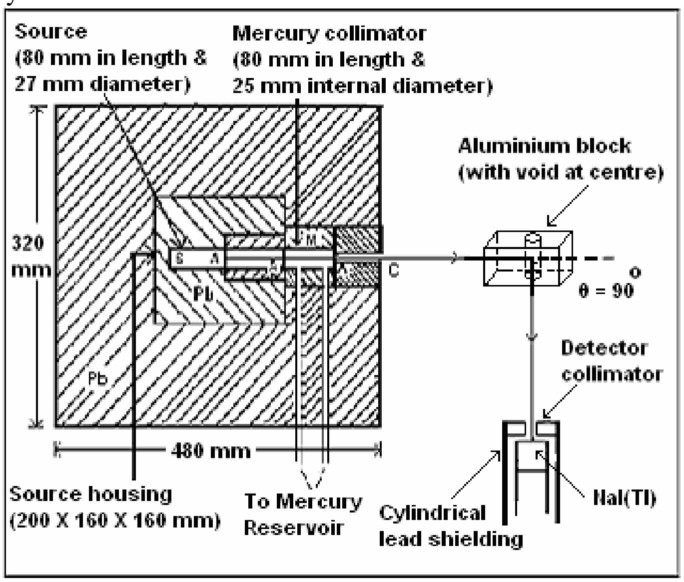

Fig. 1: Experimental set-up of present measurements. S – radioactive source; A- aluminium window; M- mercury collimator; C-fine beam collimator; Pb- Lead

^{137}Cs radioactive source, having strength 222 GBq (6-Ci), irradiates the rectangular aluminium block of dimensions 70 mm in length, 12 mm in breadth and 48 mm in height. Keeping in mind the biological effects of radiation, the radioactive source is properly shielded[4]. One long cylindrical void (simulating flaw) of diameter roughly 8 mm at the middle of aluminium block has been drilled in a direction perpendicular to the direction of incident beam. NaI(Tl) scintillation detector (shielded by a cylindrical lead shielding) having dimensions 51mm x 51mm is placed at 90° to the to the primary incident beam such that area of intersection (voxel) of collimated source beam and detector's field of view lies at the area of interest (void in aluminium block). Source and detector collimators (hole-size of each is 4 mm in radius) are used to define the volume of interest. The distances of symmetry axis of the void (in aluminium block) from the source and detector collimators are kept 338 mm and 222 mm respectively, so that the angular spread about the median ray in direction of gamma ray detector is limited to $\pm 1.07^{o}$. The choice of scattering angle of 90^{o} provides the smallest and most symmetrical scattering volume. Cylindrical rods of Al, Fe, Brass and Pb are used (simulating inclusions) one by one to fill the long cylindrical void in aluminium block and scattered spectra are recorded for different inclusions. The scattered spectra are recorded by filling void in aluminium block with different density materials. The same procedure is repeated for empty void and by filling the void with liquid Hg.

In the present measurements, the data are accumulated on a PC based ORTEC Mastreo-32 Multi channel analyzer (MCA). The sample-in scattered spectra are recorded for a period of 1 ks by filling the void with material having different density. The background is recorded for the same duration of time after removing the object sample from the primary gamma beam, this results in registration of events due to other processes independent of block under inspection. Curves ‘c’ in Fig.2 show typical observed spectrum (after subtracting background) by filling the void of aluminium block with iron cylinder.

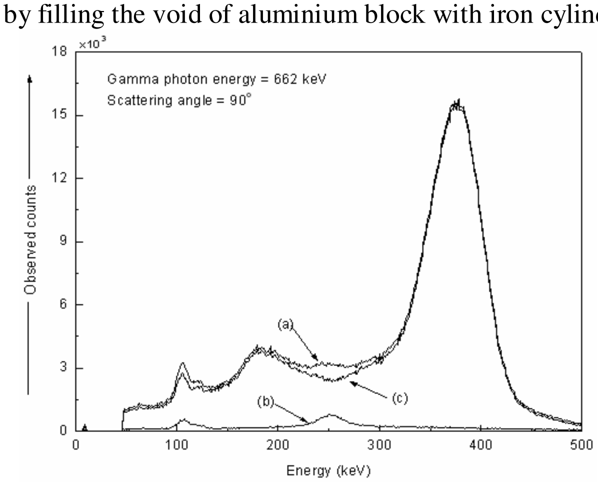

Fig. 2: A typical observed scattered spectrum (Curve-a) with aluminium block (void filled with iron rod) when irradiated by 662 keV incident photons. The background spectrum (curve-b) recorded after removing the aluminium block out of the primary gamma beam, and curve-c is the experimental observed spectrum (after subtracting background) corrected for events unrelated to sample under inspection

RESULTS AND DISCUSSION

The measured values of Compton intensity for defect/inclusion at scattering angles of 90^o are given in columns 3 of Table 1 and their plot as function of density is shown in fig. 3. The information obtained by this technique is strongly related to the material density, thus allowing changes in the material uniformity to be monitored. Scattered radiation are found to be proportional to the density of inclusive material (after applying corrections for absorption in air and within aluminium block).The results presented are not corrected for multiple scattering effects, showing that defect or inclusion (density variation) can be detected directly from the raw data. Based on the use of Compton scattered photons to derive information about discrimination between material density, this technique can be used in different medical and industrial applications. It can be concluded that Compton scattering has the potential to evaluate the materials of interest non-destructively. It is also observed that further work is required to do scanning of the whole object by step wise motion of object or detector, so that density inspection for whole object (may have multiple defects) can be stated.

Table 1: Measured values of scattered intensity originating from interactions of 662 keV gamma photons with aluminium block (having void, filled with different materials). The numbers in brackets indicate statistical uncertainties only.

Sr. No.	Name of Defect/Inclusive material	Density of defect/ Inclusive (gm/cm^3)	Scattered Intensity
1	Aluminium	2.698	2816785 (1678)
2	Iron	7.874	2915891 (1708)
3	Brass	8.5	2995596 (1731)
4	Lead	11.342	3686910 (1920)
5	Mercury	13.5336	3854299 (1963)

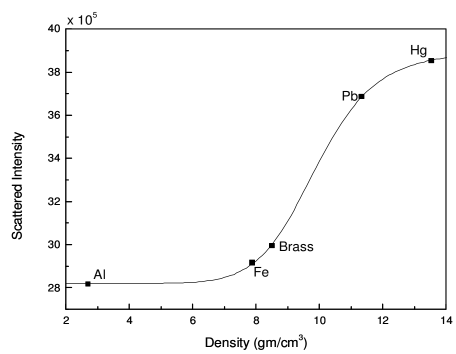

Fig. 3: Observed variation of scattered intensity versus density of different materials

REFERENCES

1. S.K. Mullin and E.M.A. Hussein, *Nuclr. Instr. & Methds A*, **353**, 663 (1994).
2. E.M.A. Hussein and T.M. Whynot, *Nuclr. Instr. & Methds A*, **283,** 100 (1989).
3. P. Zhu, G.. Peix, D. Babot and J. Muller, *NDT & E International*, **28**, 3 (1995)
4. M.B. Saddi, B. Singh and B.S. Sandhu, *Nuclr. Instr. & Methds B*, **266**, 3309 (2008).