Application of Radiometry Technique for Quality Control of Different components in Nuclear Industry

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Abstract

Radiometry is a specialize non-destructive technique where attenuated gamma beams are detected by radiation detector. The result is available in the form of counts and it provides real time information of the job. In nuclear industry, radiometry is being increasingly used for quality control of different components such as packing density variation of poison material in control rod, shielding adequacy check of reactor components, pipe line corrosion detection etc. Unlike radiography inspection, this technique require low strength radiation source and therefore is associated with less radiation related hazards. The whole set up is inexpensive and radiation detection efficiency can be increased by use of solid scintillation detector. Also in case of insulated pipeline inspection, it does not require to remove insulation layer and thus avoiding shut down of operation during inspection. This paper describes two such application of radiometry technique. In one application, radiometry technique is used for checking packing density variation of poison material in control rod. In other case, corrosion detection of pipeline by radiometry is discussed.

Keywords: Radiometry, Gamma Scanning, Pipeline corrosion

1.0 Introduction

All engineering components to be used in nuclear industry are strictly monitored for their quality to ensure excellent performance without premature failure during their service life. Although conventional non-destructive methods provide satisfactory results in most of the applications, there are certain instances where specialized techniques are used to improve reliability of inspections. Radiometry is specialized technique where radiation beam is sensed by radiation detector. The output of detector is either pulse type resolved with time or continuous analogue signal. There are different type of detectors such as gas base detector, semiconductor detector, scintillation detector, thermo luminance detectors are available for gamma ray detection. Among these, scintillation detector is widely accepted for industrial application as it is rugged, high detection efficiency and portability. In radiometry, attenuated beam detected by scintillation detector, are analyzed to obtain different attributes of scanned objects.

2.0 **Principle**

Radiometry is a technique where gamma rays from a radiation source pass through the material and attenuated beam is detected by a radiation detector. The result is available in the form of counts, i.e. number of pulses recorded in the gamma counting device. The attenuation of gamma rays in a solid medium follows the Beer-Lambert law.

$$I=I_0\exp(-\mu\delta x)$$

Where I_0 and I are intensities of incident and transmitted radiation respectively, μ, δ and x are mass attenuation coefficient, density and distance traversed respectively. Taking natural logarithm both sides of Beer-Lambert law yields.

$$\ln(I)=\ln(I_0) - \mu\delta x$$

Since photon flux recorded in a detector is proportional to intensity of radiation, the above equation can be written as

$$\ln(\text{counts})=\ln_0(\text{counts}) - \mu\delta x$$

In the above equation, the counting of incident beam is fixed for given setup and mass attenuation coefficient is also constant for a given material and is independent of it's physical form. Therefore ln(counts) is a direct linear function of density and distance traversed.

3.0 Counting Machine Setup

The heart of radiometry setup is radiation detector. Gamma rays interact with scintillation detector and emit visible light. The light energy thus produced by scintillation detector impinges on the photocathode of photomultiplier tube, producing a pulse of electron. The number of electrons thus produced is proportional to flux of incoming photon. This electron pulse is then augmented by imposing an electric field across the number of dynodes. The output of photomultiplier tube is charged pulse. This signal must be amplified into signal suitable for pulse height analysis. This is done with the help of linear amplifier. The output signals from linear amplifier has an amplitude related to energy of radiation beam. The signal from linear amplifier is sent to electronic instruments, called pulse height analyzer. The simplest pulse height analyzer is single channel analyzer(SCA), which consist of differential discriminator and a scalar. Discriminator simply rejects all signals with an amplitude less than bias setting and window is set on discriminator to receive all signals below the upper limit of window, i.e. it measures pulses lying between $E+\Delta E$. The output of SCA is fed to display circuit such as counter or visual display unit which display information regarding the number of pulses per unit time which have height falling between selected limits. The schematic diagram of a radiometry set up is shown in figure 01.

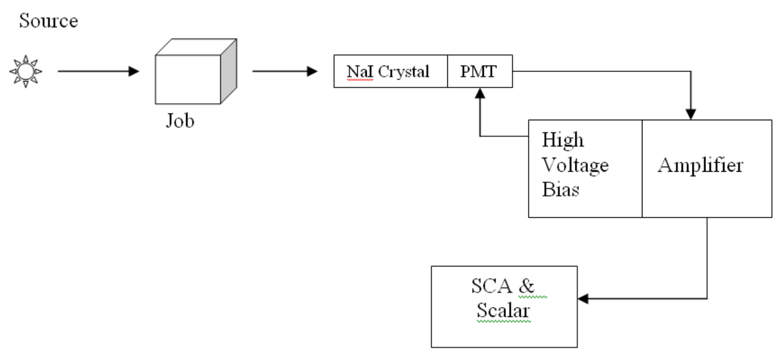

Figure 01: Schematic diagram of the radiometry set up

4.0 Quality Control of BPR by radiometry

Burnable poison rod(BPR) is important component for fuel cluster of Light Water Reactor as it maintains stable flux profile in nuclear reactor. When the fuel is fresh, it's reactivity is more, the poison material in BPR absorbs additional neutrons. After sufficient burn up, the reactivity of fuel cluster goes down with simultaneous depletion of poison material in BPR and thus maintaining constant flux profile in reactor. Radiometry is used to ensure uniform distribution of heavy poison material along the length of pin. Active gamma scanning is used for quality control of BPR pin where collimated source is used. The pin is passed between source and detector housing. There are large number of variables whose values need to be fixed at design stage or during operation. These are linear & rotary speeds, collimator slit length & width, source strength, acquisition time etc. As they influence the overall accuracy of the result, their interdependence should be understood. These variables are selected to obtain the best possible result. First the system is calibrated with standard elements and a relationship established between linear density and counts. Once system is calibrated, the signal obtained from the detector is fed to counting electronics which processes data and finally display poison material distribution along length in monitor as shown in figure 02.

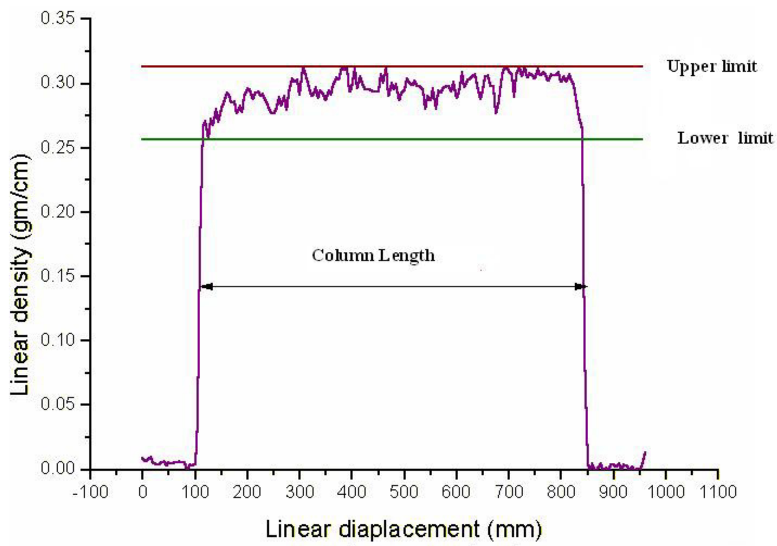

Figure 02: Poison material distribution along the length of pin

5.0 Pipeline Health Monitoring

The pipeline is important engineering component in process industry as it is used to transport fluid from one location to other location. Degradation of material with time is a common occurrence in many applications. It affects the process in two ways. Either the wall of pipe gets corroded with time or some insoluble material deposits on pipe wall. In both cases, the performance of pipeline is affected adversely. Therefore careful monitoring of pipe health is required to avoid undesired shutdown of operation. Radiometry can be used to assess the pipe wall thickness. As the attenuation of gamma photon is exponential function of pipe wall thickness, the variation in wall thickness will be reflected in change of counts. A schematic arrangement for gamma scanning of pipe line is shown in figure 03.

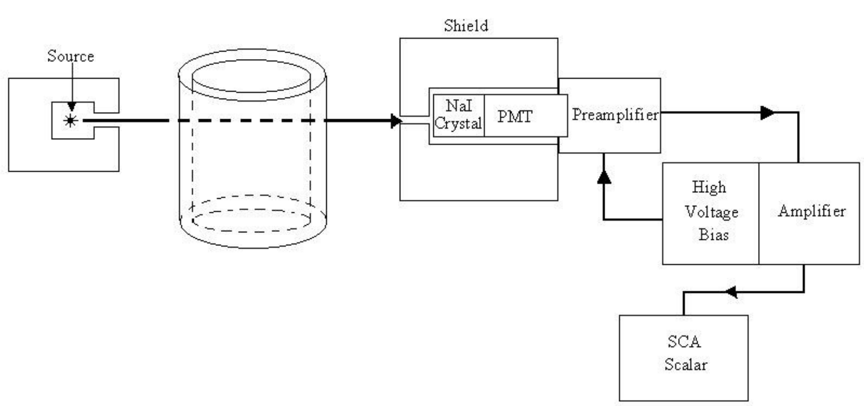

Figure 03: Schematic arrangement for radiometry scanning of a pipe.

Scanning is carried out in steps with given pre set time. After each run, pipe was rotated by 5 mm circumferential travel before next scan. Since radiation is penetrating both the walls during scanning, only 180^0 scan is sufficient for complete the circumferential coverage. A scanning profile for a pipe containing three artificial notches of different depth is shown in figure 04.

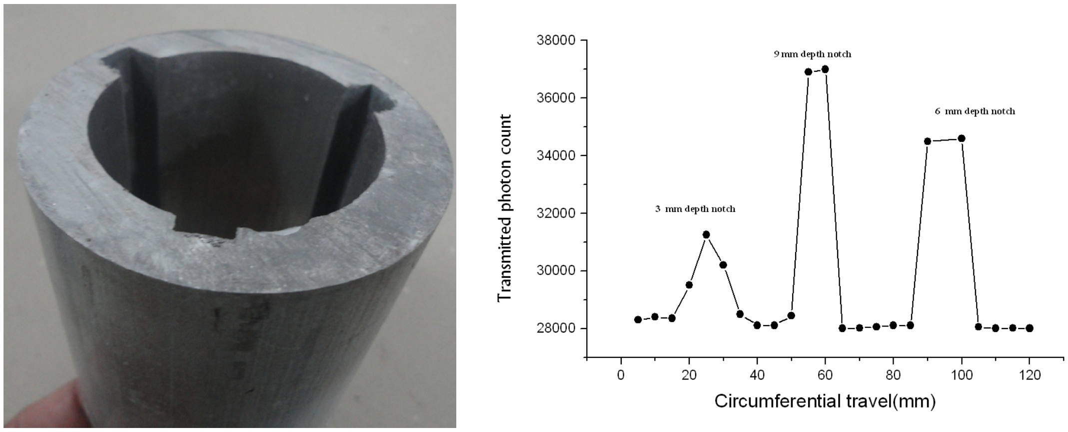

Figure 04: Notched pipe sample and it’s scanning profile

As shown in figure, during scanning count value suddenly increases over average counts at the location of notches. The extent of rise in counts depends on degree of wall thinning. In order to correlate the residual wall thickness with count data, a standard pipe containing several notches with variable depth is scanned to generate reference count data. As the projected collimated beam consist of certain finite area, this method is suitable for detecting uniform corrosion i.e. wall thinning, and to monitor the undesirable deposit on pipe wall.

6.0 Conclusion

Radiometry is a promising technique in radiation base inspection technique. If offers speed and decision can be taken in real time mode. Indigenous gamma scanning instruments are available in market and therefore cost of counting electronics are low. As it uses very low activity source, radiation dose received during inspection is extremely low and chances of radiation related accidents is less.

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