SCANNING CHARACTERISTICS OF A 3 MEV MULTIPURPOSE ELECTRON ACCELERATOR

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ABSTRACT

Electron accelerators are becoming increasingly significant in various applications, including in the electronics industry, as well as in agriculture, environmental and industrial processes. The electron beam from the accelerator is mono-directional. It is scanned using a magnet to ensure a uniform dose is delivered to the product during irradiation. Accurate measurement of the electron beam width and beam spot size is critical as it influences the performance of electron accelerators. In this study, we have presented a method to determine the electron beam width and the beam spot size in a 3 MeV multipurpose electron accelerator. Calibrated cellulose triacetate (CTA) film strip dosimeters were used for the measurement of beam width and beam spot size along and transverse to the scanning direction at a 160mm (in air) under the beam extraction window to the conveyor in dynamic (conveyor) and static modes of operation. The results showed that the electron beam width was 1130 mm with ±5% dose uniformity. The spot full width at half maximum (FWHM) of the 3 MeV multipurpose accelerator was about 64 mm. This study provides valuable insights and references in the practical applications of electron accelerators.

ABSTRAK

Pemecut elektron semakin penting dalam pelbagai aplikasi, termasuk dalam industri elektronik, pertanian, alam sekitar, dan perindustrian. Alur elektron daripada pemecut adalah bergerak dalam satu arah. Ia diimbas menggunakan magnet untuk memastikan dos yang seragam disampaikan ke produk semasa penyinaran. Pengukuran yang tepat bagi lebar alur elektron dan saiz titik alur adalah kritikal kerana ia mempengaruhi prestasi pemecut elektron. Dalam kajian ini, kami telah membentangkan kaedah untuk menentukan lebar alur elektron dan saiz titik alur keatas pemecut elektron serbaguna 3 MeV. Dosimeter jalur filem selulosa triasetat (CTA) yang telah ditentukur digunakan untuk pengukuran lebar alur dan saiz titik alur sepanjang dan melintang kepada arah pengimbasan pada 160mm (di udara) di bawah tingkap pengekstrakan alur ke konveyor dalam mod dinamik (konyeyor) dan mod operasi statik. Keputusan menunjukkan bahawa lebar alur elektron ialah 1130 mm dengan keseragaman dos ±5%. Lebar penuh titik pada separuh maksimum (FWHM) bagi pemecut pelbagai guna 3 MeV ialah kira-kira 64 mm. Kajian ini memberikan pemahaman yang lebih dan rujukan yang berharga dalam aplikasi praktikal pemecut elektron.

Keywords: electron beam, radiation processing, beam profile, dosimetry systems

INTRODUCTION

Radiation has been a crucial tool in various fields such as in nuclear physics, nuclear engineering, chemistry, and isotopes since its discovery in 1895 by Roentgen. Presently, radiation is crucial for manufacturing products such as heat-resistant electrical wires, rubber materials, and heat shrinkable tubes. Electron beams and gamma rays are primarily used in radiation chemistry, with electron beams being widely preferred due to their ease of handling. Not requiring catalysts and offering precise reaction control, electron beam processing systems have become instrumental in industrial processes such as crosslinking, graft polymerization, and sterilization. NHV Corporation's focus on powerful electron beam systems underscores the significance of this technology in modern industries [1,2].

The evaluation of the electron beam profile of an electron beam accelerator needs to be carried out to study characteristics of the beam. The beam width is measured by placing dosimeter strips or discrete dosimeters at selected intervals over the full beam width and at a defined distance from the beam window [3]. The beam width is perpendicular to the conveyor's movement at the facility. Beam length (spot size) is a dimension of the irradiation zone along the direction of the conveyor's movement at a specified distance from the accelerator window. Figure 1 shows beam length (spot size) and beam width for a scanned beam using a conveyor system. Figure 2 shows a typical irradiation setup in irradiation facilities equipped with a conveyor. The scan width often exceeds the width of the carton boxes (BW), resulting in additional electron beam losses. In most accelerator designs, the scan width can be adjusted by modifying the current level in the scanning electromagnet. While this adjustment improves the beam utilization coefficient, the conveyor system must also be adapted to ensure that the cartons remain centred relative to both the scanning device and the conveyor [4].

Malaysian Nuclear Agency has multipurpose electron accelerators (EPS-3000) which have been installed in 1991 utilized for commercial and R&D irradiation. It has the advantage of having variable energy ranging from low to high with good dose uniformity [5]. This study involved the characterization of the beam width dan beam spot size of a multipurpose electron accelerator (EPS 3000). These measurements are essential to understand the beam characteristics, for commissioning of the machine and for ensuring regular calibration accuracy.

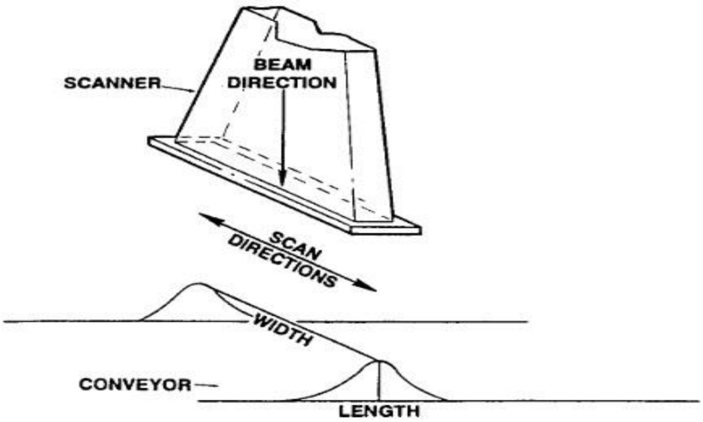

Figure 1. Beam width and beam length (spot size) for a scanned beam using a conveyor system [3].

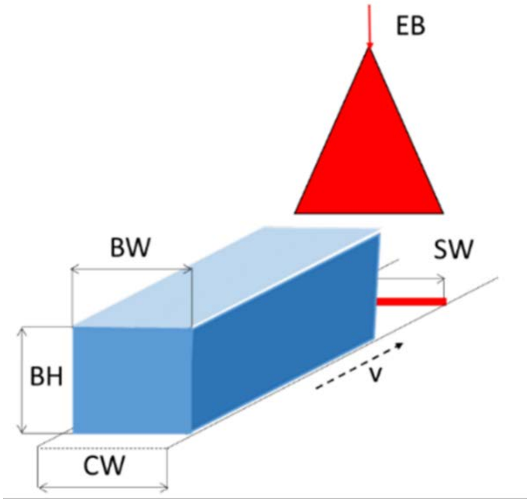

Figure 2. Typical geometry of irradiation process performed in an accelerator facility with conveyor under beam equipment: EB – electron beam, CW – conveyor width, SW – scan width, BW – carton box width, BH – carton box height, v – conveyor speed. Carton box maximum cross-section (BW × BH) [4]

METHODOLOGY

The irradiations were carried out on a 3 MeV Multipurpose Electron Accelerator of Nissin-High Voltage Co, Ltd. with the specifications as given in Table 1. Measurement of beam width and beam spot size was carried out by exposing strips of dosimeter films along and transverse to the scanning direction under the beam extraction window in dynamic (conveyor) and static mode of operation. CTA films supplied by Fuji Film Co., Ltd were used in this study with the specification as shown in Table 2.

Measurement of beam width was carried out by the exposing of dosimeter films parallel to the direction of the scan electron beam. Three dosimeter strips of more than 1650 mm were mounted on a wooden board for irradiation. This length was more than the dimension of the exit window to ensure that the radiation zone covered the lateral size of the expected process load to be irradiated. Measurements were taken in the 160 mm (in air) distances below the beam extraction window to the conveyor or carrier with 3 MeV electron energy, 1mA current and 0.89 m/min conveyor speed in 8 passes.

For the beam spot size measurement, two strips of CTA more than 1650 mm were on a wooden board parallel to the conveying direction as shown in Figure 3. For the irradiation of the dosimeter, the accelerator was operated in the static mode for 5 seconds at 3 MeV electron energy, 2mA current and 0.89 m/min conveyor speed, 400 mm from the end of the sample. The measurement along the strips provided dose distribution along the beam length. The optical absorbance of all CTA dosimeters was measured at 280nm along the entire length of the dosimeter strip with an Aer'ODE dosimetry system (Spectronic Genesis 5 spectrophotometer) from Aerial [6].

Table 1. Specifications of the EPS 3000 electron accelerator characterised in this work

Energy	0.5 - 3.0 MeV
Beam Current	1.0 - 30.0 mA
Conveyor speed	1.0 - 20.0 m/min
Max Power	90.0 kWatt

Table 2. Specifications of the CTA films

Film thickness	125 μm (15mg/cm2)
Dimension	width: 8mm, length: 100m/reel
Composition	cellulose triacetate, triphenyl phosphate
Analyzing wavelength	280nm
Usable dose range	5kGy - 300kGy

Figure 3. The experimental setup for the beam spot size measurement

RESULTS AND DISCUSSION

Figure 4 shows the beam width measured along the scan direction below the accelerator beam exit window in the dynamic mode of operation. The beam width may be defined as the distance between points along the dose profile which is at 90% of the maximum dose region in the profile [7]. The beam width needs to be sufficient to cover the entire irradiation area for processing the products [8]. It was seen in Figure 5 that the electron beam width was 1230 mm with uniformity of 95% to 113% due to higher dosage at the scanned beam edges. In our facility, we had considered a better uniformity would be achieved in the centre of the scanned beam where a ± 5% dose uniformity could be achieved for a width of 1130 mm. Thus, it was essential to limit the dimensions and position of the product within this area to ensure consistent dosage during irradiation. The farthest ends on the left and right sides were generally impractical for most industrial purposes because of the dose uniformity.

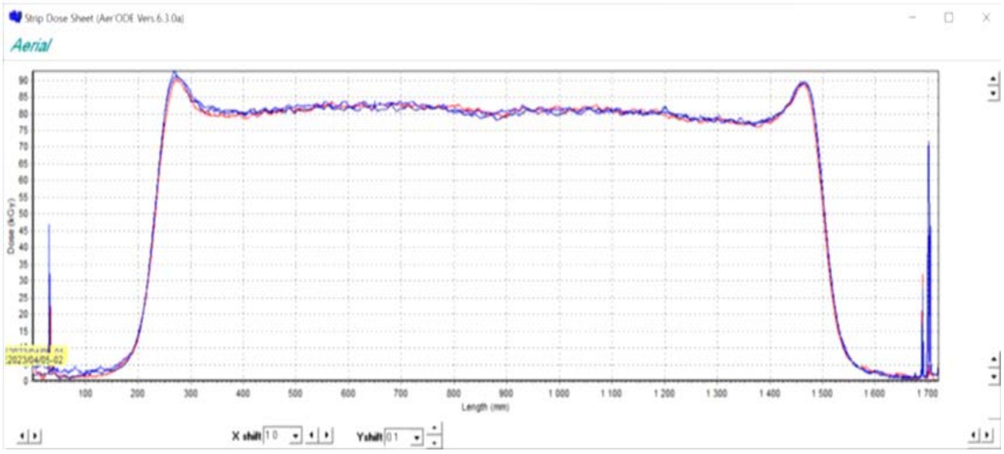

Figure 4. Beam profile (beam width) measured along the scan below the accelerator beam exit window in the dynamic mode of operation

Figure 5 shows the beam profile perpendicular to the scanning direction beneath the exit window of the accelerator in a static operational mode. It could be seen that there were two parts, one homogeneously irradiated portion and a gaussian shape peak which represented the beam spot size. The two CTA strips showed a good consistency. Beam spot size is crucial for processes where the product remains stationary under the beam to ensure uniform dosage (8). Figure 6 shows the Full Width at Half Maximum (FWHM) of these beam profiles at 160 mm heights of the conveyor from the exit window. At 160 mm from the scanner window, the FWHM measured was about 64 mm.

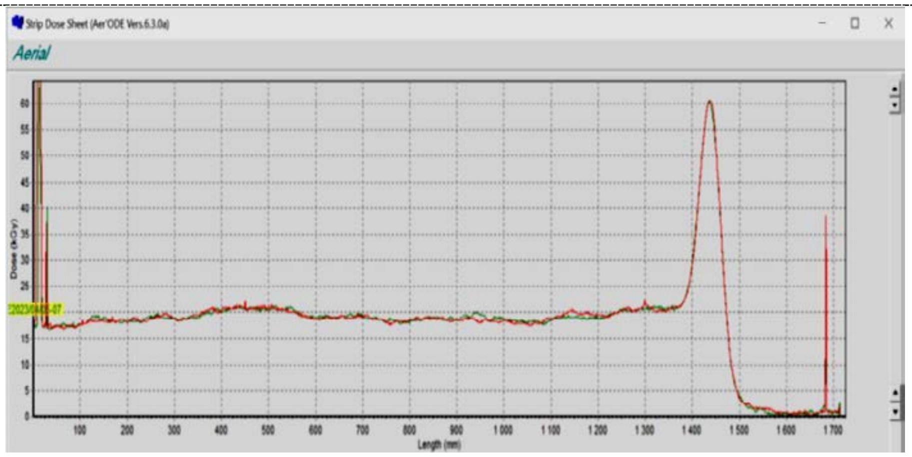

Figure 5. Beam profile (spot size) transverse to the scan direction below the accelerator beam exit window in a static mode of operation

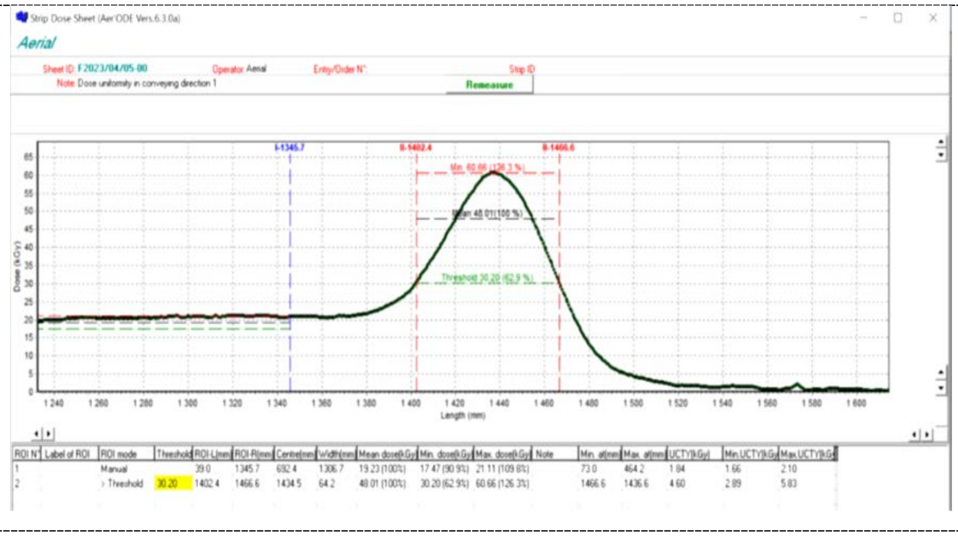

Figure 6. FWHM of beam profiles at 160 mm heights of the conveyor from the exit window

CONCLUSIONS

An experimental assessment of the scanning characteristics was conducted using a 3MeV multipurpose electron accelerator. In the dynamic mode, the measured beam width along the scanning direction showed uniformity. The beam width at 90% of the maximum dose region in the profile was 1130 mm. The beam spot size at 160 mm from the scanner window was measured to be about 64 mm. The size of the irradiation zone is directly related to the electron beam width. This dimension depends on the accelerator's specifications, particularly the exit window length. Hence, both beam width and spot size are critical parameters that must be carefully controlled within operational limits for electron beam accelerators to optimize efficiency in the irradiation process. The insights and lessons learned from this facility will drive enhancements in future systems.

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