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THE STUDY OF THE LENGTH AND SHAPE OF BEAM IN A HIGH POWER ELECTRON ACCELERATOR

M. Salehi†, F. A. Davani, B. Ghasemi, Shahid Beheshti University, Tehran, Iran
F. Ghasemi, A. Poursaleh, Nuclear Science and Technology Research, Tehran, Iran

Abstract

The output beam of a high-power linear accelerator, used for industrial purposes, is irradiated on products and scanning them. In order to improve the dosimetry of radiation which products received and to prevent loss of the attacked- beams to the edge of products, the exact evaluation of scanning length is necessary. One of the other challenges of the scanning beam is the lack of uniformity in dosimetry of received radiation. The scanning beam does not collide in parallel to the products, which is also a challenge to accelerator efficiency. To improve dosimetry of received radiation, the use of trajectory correction magnets is suggested. These magnets correct the beams that do not scan in parallel. Also, using the Monte Carlo code, the dosing rate of received radiation to products is simulated and compared in two non-uniform and uniform modes (corrected by trajectory correction magnets).

INTRODUCTION

Various types of industrial accelerators have different applications in the industry by providing an electron beams with energy range of 0.5 to 10 mega electron volts. In these accelerators, the irradiation rate of the products depends on the current and the power of the electron beam. In these accelerators, the irradiation rate to the products depends on the current and the power of the electron beam. At the present, the use of industrial electron accelerators in Iran is restricted to the Yazd radiation monitoring center of the Atomic Energy Organization, which uses TT200 rhodotron accelerators to irradiate their products [1]. At the present, the use of industrial electron accelerators in Iran is restricted to the Yazd radiation monitoring center of the Atomic Energy Organization, which uses industrial accelerators to irradiate their products. In each industrial electron accelerator, the beam enters the extraction beam section after accelerating in the acceleration part. Figure 1 shows the components of the beam extraction system of the industrial accelerator in Yazd. The diameter of output electron beam of industrial accelerators such as linac accelerators is about 1 cm to 2 cm. Therefore, to irradiate it to the product, it is necessary, the beam enters the sweeping magnet. The sweeping magnet is placed at the beginning of the horn and swept the beam into the horn according to the required scan length. Therefore, in a static state the affected cross section has same dimension of beam diameter. Therefore, it is necessary to move the box in front of the beam at the appropriate speed, which is proportional to the amount of doses required. In Fig. 1, the effect of the sweeping magnet on the electron beam is obvious.

The Power supply of the sweeping magnet is such that it starts to sweep the beam linearly from a minimum magnet current and changes with the increase of the current of the scanning angle, so that the minimum and maximum flow rates are in accordance with the angles of the beam in the two corners of the horn. The beam extraction system horn in industrial accelerators is actually a vacuum chamber, which is maintained with a suitable foil of titanium, which is vacuumed relative to room air. Determining the exact length of the scan in Horn and the need to correct the path of the beam in it, are discussed in this article [2].

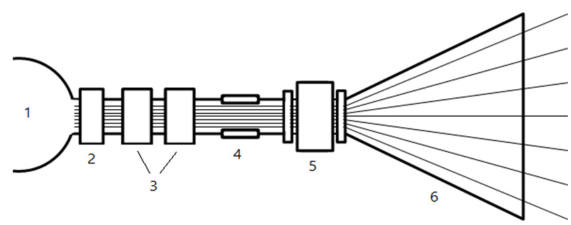

Figure 1: Components of extraction system and transmition of output beam of Linac accelerator. 1) accelerating structure, 2) control magnet, 3) quadrupole doublet, 4) diaphragm, 5) scanning electromagnet, 6) horn.

CHECK THE IMPORTANCE OF DETERMINING PRECISELY AND APPLYING SCAN LENGTH

In industrial accelerator of Yazd radiation center, the output beam of the accelerator at the beginning of the Horn are swept with a frequency of 100 Hz by a sweeper magnet in a way which some of the beams does not collide with the product, and part of the beams does not irradiate products completely and in fact part of power of input beam is wasted. This issue affects the irradiation efficiency.

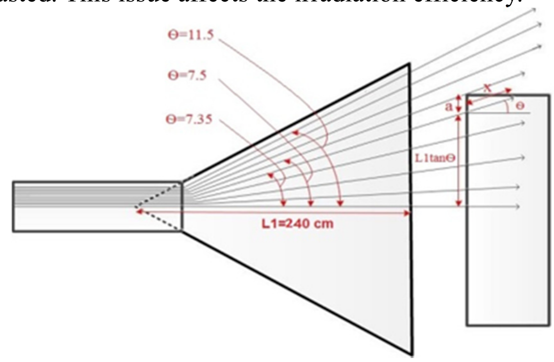

Figure 2: Geometrical parameters at the horn of the beam extraction system.

† Mohammad7salehi@yahoo.com

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In Fig. 2, a plot of what is happening at the accelerator Horn in Yazd is shown. In this figure, the dimensions are according to reality. As can be seen, according to the dimensions of the horn, including its length and angle, and also the dimensions of the boxes and their distance from the horn, the beam will not hit the product. Studies show that in fact, in the center of irradiation in Yazd, the beam is swept up to 11.5 degrees by the corresponding magnet. This item is used to ensure that the box is properly exposed. Independent of the sweeping frequency, according to (1), the beam does not collide with the product box. Due to the dimensions of the horn of industrial accelerator in the center of Yazd, and the distance between the product box and the Horn, the scan angle is at most 7.5 degree corresponding to the hitted beam to the product box. As a result, product box in not exposed in angle between 7.5 to 11.5 degrees.

ratio of non-collision = (2×(11.5-7.5))/(2×11.5)= 35%

This calculation shows that about 35% of the power of the beam does not hit the product. For example, if the nominal output power of the accelerator is 100 kW, then 35 kilowatts will not reach the product. With an efficiency of 40% for the Rhodotron TT200, 87.5 kW of power consumption will actually be wasted. The results show that an accurate re-examination of the scan length proportional to the dimensions of box is significant, and this issue requires high precision in each irradiation center. The collision of the divergent beam to the box also causes non-uniformity in the curve of percentage of deep dose. In fact, applying a divergent beam change shape of the curve of percentage of deep dose depending on the angle of inclination, α, which is the angle between the central axis of the beam and the perpendicular axis of the product. The larger angle results decreasing in depth of maximum dose and increases the magnitude of the maximum dose. Increasing dose is due to increasing of the electron flux on the central axis of the electron beam [3]. A comparison between these two states of divergent and perpendicular collision, was performed using Monte Carlo simulations in the MCNPX code to examine the power of output beam exits from horn of the industrial electron accelerator. To reduce simulations, one-way radiation is considered. To simulate the divergent collision, assume a source corresponding an electron beam with a diameter of 2 cm above the box with dimensions of 45 cm × 45 cm × 22 cm that containing spice with a density of 0.6 cm3.

For perpendicular collision is also considered to be a source with dimensions of 2 cm × 90 cm above the box. The box is also meshed with a 1 × 0.2 cm square in the transverse plane. The output of these simulations is processed using the MATLAB program, and Fig. 3 shows the distribution of doses in the transverse plane of the beam. In Fig. 4, the difference in the distribution of doses in the box is observed in both the normal and divergent radiation conditions. In the corners of the box, the maximum dose is closer to the surface, indicating the non-uniformity distribution of the dose.

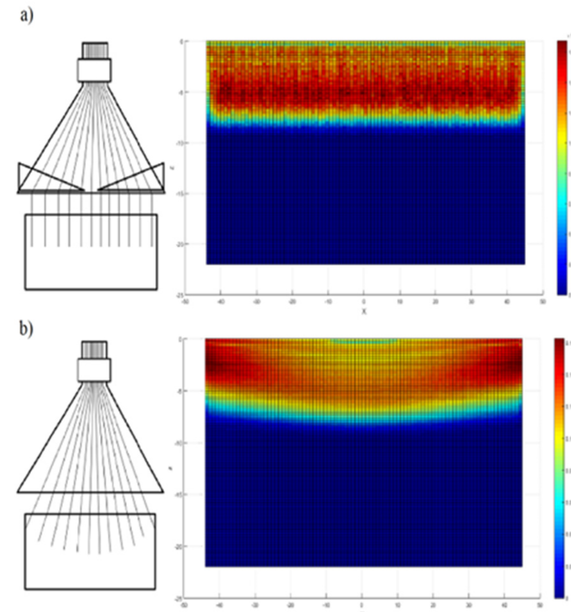

Figure 3: Distribution of doses on the transverse plate. a) perpendicular irradiation. b) divergent irradiation.

As mentioned above,in many radiation center such as in Yazd's center using the scanning angle larger than box length to ensure definite radiation exposure of the products. By this choice, the undesirable effect of moving the box on pallets located on the corresponding conveyors is also eliminated. But this item can be repaired by implementing the proper mechanism for the exact location of the boxes and there is no need to increase the length of the scan for this purpose. . Another solution to fix this problem is the use of suitable magnets on both ends of the horn to direct the beam with larger angles into the product box. In addition to fixing this problem, this magnet can also be effective for perpendicularity the beams which irradiate product, which is discussed in the next section of the paper.

CONCEPTUAL DESIGN OF CORRECTION MAGNET

Before the design of the correction magnets of the electron beam path, for the verification of their designs and simulations, the bending magnets in the Yazd center accelerator were simulated and compared with experimental values. For different energies for the electron beam, the required current in the coils and the magnetic field generated by the magnet, is calculated. These values are compared with the experimental values measured by the magnetic probe. For example, in an energy of 3 MeV, the error of measurements between simulation and experimental values is 13% and 12% for the magnetic field and current, respectively. But magnets used to correct the electron beam path at the end of the horn are of the C-shaped type of bipolar magnets. By applying the current to coils of magnet, the magnetic field is created between the magnet's gap. Magnet's cores are in the form that exposure a larger magnetic field as the beam bends towards the coils. Therefore,

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any particle that travels longer in the distance between the gaps will have more magnetic force and a larger deviation.

These magnets were simulated using the CST STUDIO SUITE 2017 software. To simulate an electron beam with energy of 10 MeV, it diverges through the inside of the horn. The maximum magnetic field designed magnets for a beam of 10 MeV and 10 mA, is about 240 Gauss.

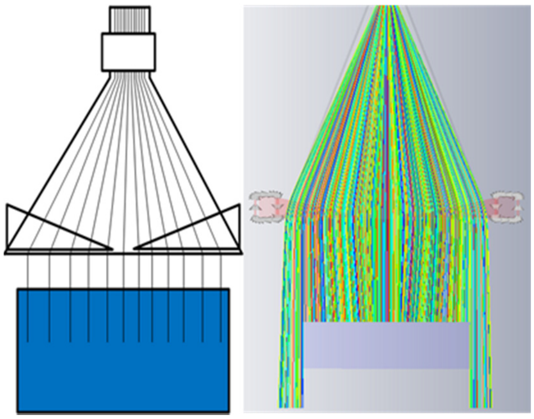

Figure 4: Use of correcting magnets located at the exit window of the horn allows changing the path of the beam.

CONCLUSION

A significant part of the output beam of industrial accelerators that is not exposed to the product due to the lack of optimal collisions it will be lost. With the calculations we found that much of the accelerator power was lost at a scan angle between 7.35 and 11.5 degrees, so that it was determined that the length of the scan should be adjusted to minimize the amount of loss. on the other hand Using magnets that correct the collision path to the product, more efficient systems can be obtained. These magnets are predicted to be about 240 Gauss with a magnetic field.

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