Optimization of Scanning Process in Accelerator for Food Preservation

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Abstract

The optimization of scanning process was done for pulse linear accelerator PILOT of 10MeV energy, average power 1kW and 4μs of pulse duration in order to achieve best uniformity of dose distribution.

The paper presents the basic data of accelerator, its application, the method and results of scanning process optimization, designed scanning system with its electronics and results of dose distribution measurement on the scanning surface.

1. INTRODUCTION

The use of particle accelerators in industry, medicine and applied research grown rapidly over the past decades. The electron accelerators are widely used for food preservation purposes.

As irradiated surfaces of processed products are of some size appears problem of assurance its dose distribution uniformity.

This problem was succesfully solved for pulse linear accelerator PILOT, intended for food processing by means of radiation.

2. BASIC CHARACTERISTICS

2.1 General description

The PILOT accelerator employs an accelerating structure with standing wave in heavy-duty operation conditions.

The beam at the output is shaped to band of about 60cm by means of transversal magnetic field produced by an electromagnet.

There are two options of accelerator operation: the first is irradiotion with electron beam at the energy of about 10MeV and the second with X-rays at the energy of about 5MeV after placing the target unit at the end of scanning chamber.

The accelerator is vertically positioned so that the plane of scanned beam is perpendicular to the food conveyer movement direction.

The distance between the output window and the conveyer surface is basically 40cm, but it could be changed if necessary.

2.2 Specifications

General data of the PILOT accelerator are given in table 1.

Table 1
PILOT accelerator specifications

Parameter Name	Value
Max. electron energy	10MeV
Total average power	1kW
Beam scanning	transversal magn. field
Dimension of the band beam	40÷60cm adjustable titanium
Beam output window	.1mm Ti (titanium) air-cooled foil
Accelerating structure	with standing wave π/2; 2998MHz
Focalisation	axial magn. field
Pulse repetition frequency	100Hz; 300Hz
Beam pulse width	4μs
Electron energy in X-ray mode of oper	5MeV
e -/X conversion target	1mm tungsten

3. APPLICATION

The use of PILOT accelerator gives the possibility of food processing in a macro--scale.

Food can be processed in thin (with electrons) as well as in thick (with X-ray beam) layers. Due to high dose rate levels, irradiating with e-beam is significantly more effective.

The doses required for food processing are enclosed in the range between 10Gy and 10kGy. The accelerator output dose rate in electron mode (on conveyer surface) is about 2kGy/min. The use of conveyer with transport speeds of about 0.2m/min to 8m/min enables covering the necessary dose ranges.

The PILOT application enables the following kinds of agriculture products processing:

- Irradiation of loose materials (e.g. dezinfestation of crops, dezinfestation and sterilization of some fodders, spices sterilization etc.) Products are processed in thin layers with 10MeV electron beam. Required doses are 300÷500Gy for dezinfestation and about 10kGy for sterilization.
- Processing of products in flat containers or parcels with the thickness of about 5cm (e.g.anion and garlic irradiation for sprouting inhibition, strawberrys irradiation for moulding and decay inhibition, mashrooms to reduce development of its caps and growing dark inhibition, packed foods for extend the period of its freshness etc.) Products are processed using 10MeV electron beam. Required doses are 100Gy for sprouting inhibition, about 2kGy for strawberrys and mashrooms and about 10kGy for sterilization.
- Processing of products in thick layers. As a working beam 5MeV X-ray beam is used. Due to low efficiency of e -/X conversion the velocity of X-ray processing is significantly lower than the velocity of electron processing.

4. SCANNING PROCESS

In order to irradiate large surfaces it is necessary to operate with the beam foremed to transversal bend. In PILOT accelerator the beam is formed by variable transversal magnetic field produced by the scanning electromagnet.

The scanning chamber dimensions enables obtaining output band beam width of about 600mm while overall dimensions of the system are quite moderate.

The scanning chamber lenght is 400mm, the field operation lenght is 70mm and maximum electrons energy is 10MeV. For those conditions and transversal dimension of the scanned electron beam on the output window of about 600mm required magnetic field induction in electromagnet core gap is 0.27T.

The scanning generator and its power amplifier produce trangular-waveform current which supplies the scanning electromagnet coils and causes appearing of adeguately varying magnetic field in electromagnet core gap. The scanning of electron beam is provided symmetrically in both directions to the chamber axis.

For the electromagnet core gap of 12mm the current flows through the coils (600 turns of winding) is about ±10A.

The optimum scanning frequency was selected to ensure the uniform dose distribution in irradiated material and to minimize output window foil heating.

5. SCANNING FREQUENCY SELECTION AND SCANNING GENERATOR

The scanning frequency was selected from the range of 0÷30Hz in purpose to minimize the looses in electromagnet coils caused by its substantial inductance at high frequencies. The beam movement during the pulse lenght (4μs) for those frequencies is practically negligible. Let us call the beam pulse marks on the irradiated surface, spots. Than, the spots distribution on the inspected plane illustrate the irradiation uniformity at particular conveyer speed.

That illustration can be simulated on the computer screen by short programme "PUNEL 1". The set parameters are: pulse repetition frequency, scanning frequency first spot time delay and conveyer speed. The "PUNEL 1" foreseen also the possibility of synchronization pulse repetition and scanning frequencies. All frequencies from the range of 0÷30Hz (at 1Hz intervals) were examined by means of the programme. It turned out that there are three scanning frequencies with good spots distribution: 11Hz, 14Hz and 19Hz. But the best uniformity is achieved at the frequency of 11Hz. The conveyer speeds taken into consideration were from the range the between 0.2 and 8m/min.

To avoid problems connecting with stability of scanning and pulse repetition frequencies the additional pulse generator setting both those frequencies was foreseen.

The pulse generator of 6.6kHz frequency used on scanning unit is a source of pulses for 11Hz generator based on digital to analog converter and after dividing by 22 gives possibility of pulse repetition frequency synchronizing. The scanning unit comprises also the power amplifier and the protection circuits.

The protection circuits provides means of protection against scanning system failure. The scanning of the beam is monitored by two ionization chamber located at the both ends of scanning chamber exit window, and additionally by signal derived from scanning electromagnet shunt. The failure of scanning system results in switching the beam off to privide safety of exit foil operation.

The uniformity of transversal bend beam dose distribution was examined by means of PCV foil and a special device consist of great number Faraday cups. The transversal uniformity of the band is about 8%.

6. REFERENCES

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