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INDUSTRIAL ELECTRON LINEAR ACCELERATOR R&D IN CIAE

Jinghe Yang †, Guolong Yu, Zhibin Zhu, Ziqiang Zeng, China Institute of Atomic Energy, Beijing, China

Abstract

Electron linear accelerator(E-LINAC) is a vital accelerator type for accelerator applications, which widely applied in industry, agriculture and medical industry. The paper introduces R&D of industrial E-LINAC in China Institute of Atomic Energy (CIAE), including electron gun, modulator, accelerating tube, assembling and testing. Based on these R&D results, the GT series for non-destructive test (NDT) and FZ series for radiation processing are developed successfully. At present these E-LINACs play important roles in pressure vessel inspection, food preservation, sterilization and material modification, promoting the E-LINACs application as well as economic development in China.

INTRODUCTION

Accelerator-based high energy X-ray source and accelerator-based high energy electron source are two kinds of important instruments for NDT and electron beam (EB) radiation processing. Both the first NDT accelerator and the first 10MeV/20kW EB processing accelerator in China were developed successfully by CIAE about 20 years ago and 10 years ago respectively [1]. After a long-term development and improvement, the NDT accelerators form a series of accelerator, so called GT series, which can generate X ray with energy ranging from 1 MeV to 12MeV. 10MeV/20kW EB accelerator for radiation processing has been widely applied in China.

NDT ACCELERATOR

The GT series is used for NDT. See Table 1.

Table 1: The GT Series Accelerator for NDT

Model No.	X-ray energy	X-ray dose rate
GT-2/200	2MeV	200cGy/min.m
GT-2D/200	1MeV/2MeV	200cGy/min.m
GT-4/500	4MeV	500cGy/min.m
GT-4D/500	2MeV/4MeV	500cGy/min.m
GT-6/1000	6MeV	1000cGy/min.m
GT-6D/1000	4MeV/6MeV	1000cGy/min.m
GT-9/3000	9MeV	3000cGy/min.m
GT-9D/3000	6MeV/9MeV	3000cGy/min.m
GT-12/5000	12MeV	5000cGy/min.m
GT-12D/5000	9MeV/12MeV	5000cGy/min.m

The letter “D” in the model No. stands for Dual-energy type.

NDT accelerator consist of modulator [2], X-ray head, cooling unit and control system [3]. This parts are connected by cables including electric power cable, Ethernet cable, signal cable and so on. See Fig. 1.

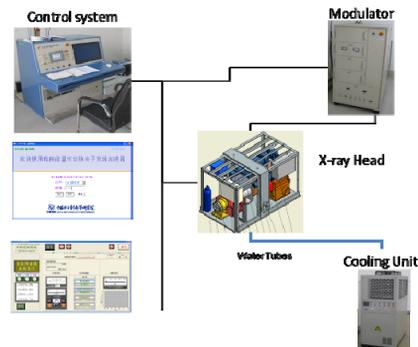


Figure 1: NDT accelerator sketch.

NDT accelerator can be used as a high energy X ray source for film imaging (see Fig. 2) and industrial CT.



Figure 2: NDT accelerator on duty.

RADIATION PROCESSING ACCELERATOR

The FZ series is used for radiation processing. See Table 2.

Table 2: The FZ Series Accelerator

Model No.	EB energy	Avg. beam power
FZ-10/20	10MeV	20kW
FZ-2/1	2MeV	1kW

10MeV/20kW accelerator is applied in EB radiation processing including sterilization, material modification and so on. 2MeV/1kW accelerator is applied in mail sterilization, radiation curing because of short penetration depth.

High Voltage Pulse Modulator

The line-type modulator is used for 10MeV/20kW to generate 130kV/90A pulse to drive the klystron. The IGBT is used for charging unit and hydrogen thyatron is used for discharging unit. The pulse forming net (PFN) generate 16 μs pulse width. The duty factor is 9%.

† 13811486349@163.com

Electron Gun

The electron gun power supply is integrated with the high voltage pulse modulator. The electron gun power supply is a pulsed power supply too. It generates 50kV pulse voltage.

Normally, we use a thermal cathode electron gun for a 10MeV/20kW accelerator. While we use a grid-control electron gun, showed in Fig. 3, for a multi-energy accelerator because the beam current can be adjusted and controlled precisely.

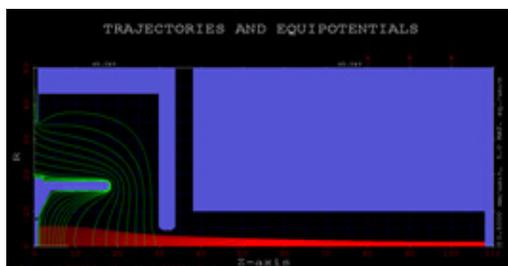


Figure 3: design of a grid-control electron gun.

Travelling Wave Accelerating Tube

The travelling wave accelerating tube [4-5] is used for 10MeV/20kW to accelerate electron beam to 10MeV. The pulse current is 300mA. The microwave power source is 5MW/45kW klystron.

Based on the disk-loaded structure, the travelling wave accelerating tube consists 58 cells, 6 of which are bunching cells. The total length is 1.97m. The tube works at $2\pi/3$ mode

SUPERFISH and PARMELA are used to calculate the electromagnetic field and beam dynamics.

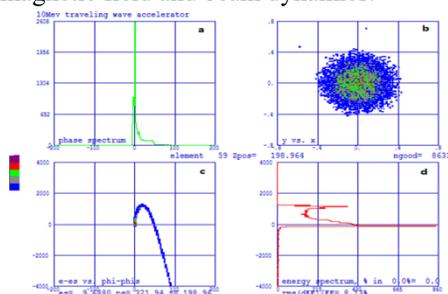


Figure 4: beam dynamic simulation with PARMELA.

As we can see in Fig. 4, most electrons within a microwave period are bunched into a relative narrow width of phase. Beam spot is about 8 mm and energy spread is less than 10% at output of the tube. The tube is showed in Fig. 5.



Figure 5: Travelling wave accelerating tube tuning.

DISTRIBUTION OF INDUSTRIAL ACCELERATOR APPLICATIONS

The industrial electron linear accelerator developed by CIAE has been applied widely in China showed in Fig. 6. These accelerators have good reliability, stability and maintainability.



Figure 6: Distribution of industrial accelerator developed by CIAE.

CONCLUSION

CIAE has been absorbed in development of industrial electron linear accelerator for more than 20 years. These accelerators has widely used in scientific research and industrial application. Most key devices and components have been developed successfully. As the rapid development of the economy and science, the requirement for the accelerator become more strict. CIAE has been studying on R&D of the new accelerator to meet the new requirement.

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