

UEL-10-D NEW LINEAR ELECTRON ACCELERATOR FOR NON-DESTRUCTIVE TESTING

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Abstract

A compact accelerator UEL-10-D intended for radiographic inspection of steel products of up to 500 mm thickness has been designed and manufactured.

The accelerator provides the 10 MeV energy of accelerated electrons and the X-ray dose rate 1 m from target of 30 Gy/min.

The accelerator consists of an irradiator mounted on a special yoke, a heat-exchanger unit and an industrial panel-type computer. Practically all the equipment of the accelerator is mounted inside the irradiator including the HV power supply system, magnetron modulator and control system blocks. Using this yoke, the irradiator is installed on a bridge crane, which ensures its high manoeuvrability necessary to test products of complicated geometry. Size of the irradiator without yoke is: 2040×950×950 mm.

In 2010, the accelerator was put into operation at the “Izhorskie Zavody”, St.Petersburg.

The UEL-10-D accelerator can be also used in radiosopic and tomographic systems.

Requirements for reliability effective in nuclear, chemical and shipbuilding industries make necessary the non-destructive testing of large products including detection and identification of different defects such as cracks, cavities, foreign inclusions, etc. For example when manufacturing atomic reactors, 100% inspection of weld seams is necessary in compliance with requirements of Gosatomnadzor and IAEA. As the thickness of products inspected can be up to 600 mm for steel, charged particle accelerators are the only tool ensuring the required inspection quality.

A series of accelerators for NDT with energies from 2 up to 16 MeV and the photon dose rate (1 m from target) from 20 up to 120 Gy/min has been developed in the D.V. Efremov Institute [1]. Technical performances of these accelerators provide necessary quality of radiographic inspection at the 1-1T level in compliance with the international standard ASTM E 142 for products with an equivalent thickness for steel up to 450 mm.

To date, more than thirty similar accelerators have been delivered to industrial enterprises in Russia and abroad. However, technological progress makes necessary updating of the delivered equipment in 10-15 years after its development. Unfortunately, in Russia deliveries of many domestically-produced component parts and units have been stopped, which impedes the process of updating. In particular, has been stopped the production

of the power klystron KIU-111 (pulse power up to 6 MW), which served as a source of the RF power in our accelerators for non-destructive inspection with an energy higher than 6 MeV. Taking into account the fact that the only our competitor in the development of accelerators for industrial radiography, VARIAN (the USA), can supply accelerators to Russia only provided a special permission of the USA government, there has been taken a solution on the designing and manufacturing a practically new domestic machine for NDT, namely UEL-10-D.

This accelerator provides the following radiation parameters: the maximum average X-ray dose rate 1m from target on the central axis is 30 Gy/min at the 10 MeV energy; the pulse repetition rates are 50 and 200 Hz; the time for the beam stabilization after its turn-on is 5 s; the range of inspected thickness for steel is 50-500 mm.

The irradiator 2040×950×950 mm in size and of 1160 kg weight is installed on the bridge crane using a specially designed yoke. The yoke enables changes of its location relative to an object under inspection: in the horizontal plane from +180° (rightwards) to -135° (leftwards) and in the vertical plane from +45° (upwards) to -95° (downwards). The irradiator is made as a support frame of aluminum section, inside which is installed practically all the equipment of the accelerator including the high-voltage power supply system, in contrast to the previous layout [1].

An electron beam with an injection energy of 50 keV is accelerated up to 10 MeV. A biperiodic standing-wave accelerating structure with axial coupling cells is applied in the accelerator. The buncher of the accelerating structure provides focusing of the electron beam under the action of accelerating RF-field, and as a result there is no need for the focusing solenoid and centering coils. The beam of accelerated electrons focused to 2 mm in diameter strikes the target wherein X-rays are produced. A water-cooled target is made of tungsten-rhenium (WRe). To measure the beam current, the target is insulated from the casing by a ceramic insulator. At the accelerator output, a collimator with a cone angle of 17° is installed. A laser is used to point the irradiator to a section inspected.

The MG-6090 magnetron with a power of 3 MW per a 3 μs pulse (the maximum average power is 2.5 kW) produced by an English firm is used as a source of the RF energy. The modulator of the magnetron forms the high-voltage pulse voltage up to 50 kV with a current of 100 A.

The modulator works with complete discharge of a storage device. A PFN, which is discharged through a

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thyatron and the primary winding of the high-voltage step-up pulse transformer, is used as a storage. Voltage from the secondary winding of the pulse transformer is supplied to cathodes of the magnetron and electron source.

The RF power from the magnetron is transmitted to the accelerating structure through the waveguide line. To increase the electric strength, the inner volume of the waveguide line is filled with sulfur hexafluoride (SF_6) at an excessive pressure of not higher than (1.25 ± 0.25) bar, which allows thin-walled waveguides to be used. To fill the waveguide with SF_6 , there is provided a tank with the gas, a reduction unit, pressure gauges and adapter fittings. To match the magnetron with the accelerating structure, a phase-shifter is usually installed in the waveguide. In our case, when the accelerator operates in the fixed-energy mode, the problem has been solved by properly choosing the waveguide length.

Power is supplied to the accelerator from an AC three-phase mains $3 \times 380 \text{ V} \pm 10\%$, $50 \text{ Hz} \pm 1\%$ with the grounded or insulated neutral. Power consumption is not more than 25 kW. The maximum total power of the heat released into atmosphere by the accelerator equipment is not more than 6 kW. The operation mode is long-term, three-shifted with one-hour break between shifts needed to carry out visual inspection of the machine.

The power switchboard and other blocks necessary for the accelerator operation are located inside the irradiator.

The control system of the accelerator [2] is made on the basis of an industrial computer. Proper measures to provide electromagnetic compatibility of high-current devices of the accelerator and the computer control system had been taken, after which we managed to house

all interface blocks of the control system inside the irradiator; only the industrial computer is located on the control desk.

Maintaining the temperature of the accelerating structure at a permanent preset level and cooling of the X-ray target and magnetron are provided by using a closed water cooling loop and a water-air heat-exchanger (RITTAL), and, as a result, the outer water cooling loop is not needed. The heat-exchanger is sufficiently compact: $640 \times 600 \times 670$ in size and 130 kg in weight and it can be located on the bridge crane next to the irradiator.

When carrying out repair works on the irradiator connected with the depressurization of the high-vacuum volume of the accelerating line, rough evacuation of this volume should be done. For rough evacuation we use a turbo-pump unit TSH 071 E (PFEIFFER), which allows the vacuum volume to be rapidly evacuated and complete conditioning of the electron source to be performed without using standard high-vacuum pumps. On finishing the repair works, the unit is disconnected from the irradiator and can be kept separately.

The layout of the equipment allowed the irradiator parameters to be minimized; moreover the outer high-voltage cable and water-cooling hose are not needed. The length of power and control cables allow the irradiator travel in the horizontal direction up to 150 m and in the vertical direction up to 10 m. The UEL-10-D accelerator is certified and is successfully operated at the “Izhorskie Zavody” open joint stock company (see Fig. 1). Similar accelerators are in demand in the heavy engineering industry (the “Atommash”, “Uralkhimmash” plants and so on) and can be also used in radiosopic and tomographic systems.



Figure 1: The UEL-10-D accelerator in a shop of the “Izhorskie Zavody” open joint stock company

REFERENCES

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