"ELECTRON-10" HIGH VOLTAGE ACCELERATOR FOR DOUBLE-SIDED IRRADIATION OF FLEXIBLE MATERIALS

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The main goals we pursued during the accelerator design and development were to develop a compact self-shielded device for flexible materials irradiation in one pass which might be installed by a Customer into common industrial premises not equipped with any lifting devices.

These goals were successfully achieved in the "Electron-10" accelerator design.

Technical parameters of the accelerator are given in the Table 1.

Table 1

№	Parameter	Value
1	Accelerating voltage	500-750 kV
2	Accelerating voltage non-stability during one hour of operation (not counting ripples with frequency 50 Hz and more), not higher	±5%
3	Beam current range (in the two-window operation mode)	0-70 mA
4	Irradiation zone size in each outlet window	1500×80 mm
5	Non-uniformity of linear beam current in the irradiation zone region on the 50 mm distance from the outlet window foil, not higher	±5%
6	Non-uniformity of linear beam current density during one hour of operation (from 10% to max value of the beam current), not higher	±5%
7	Scan frequency along the outlet windows, not less	300 Hz
8	Window to window beam transfer frequency range (regulated)	20-50 Hz
9	Average operation time between prophylactics, not less	200 h
10	Technical use coefficient determined as Ctu=operation time/(operation time + prophylactics), not less	0,85
11	Ionizing irradiation dose power on the outer surface of the radiation shielding A/kg (mR/h), не более	1,003×10-10 (1,4)

The accelerator consists of a high voltage generator, an accelerating structure, and systems providing beam irradiation field forming, power supplying and control. Auxiliary equipment and set of spare parts for at least one year of operation are also included into accelerator specification. "Electron-10" accelerator during its training at the institute testing facility is shown in Fig. 1.

Fig. 1.

High voltage generator of the accelerator is built on the base of a single-phase transformer-rectifier, (Fig. 2, plane view) similar to the accelerators described in [1, 2], one of its distinctions is a horizontal orientation of the HV generator and accelerating structure. Conical primary winding of the HV generator made from the water-cooled copper pipe is fastened inside an insulating frame that allowed to minimize distance between primary and secondary windings of the transformer-rectifier and thus improve the magnetic coupling between them.

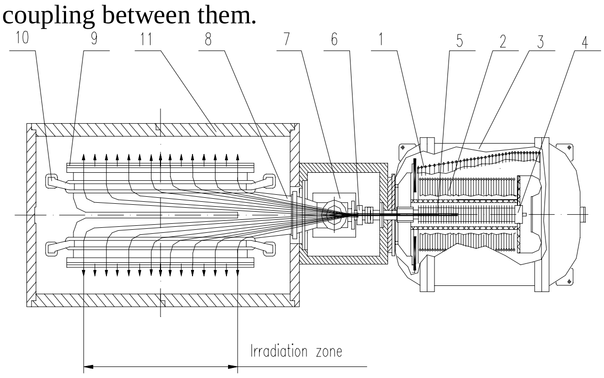

Fig 2

1 - Primary Winding
2 - Secondary Winding
3 – High - Pressure Tank
4 – Electron Source
5 –Accelerating Tube
6 – Scanning Device
7 - Vacuum Pump
8 - Vacuum Chamber
9 - Outlet Window
10 - Turning Magnet
11 - Local Radiation Shielding

The secondary winding is combined from the 27 rectifying voltage-doubling modules; the module average DC voltage is 27,5 kV. The modules are placed on the insulating supporting bar made from organic glass. Position and form of each coil of the primary winding has been optimized by numerical simulation of magnetic and electric field that allowed, firstly, to get rather homogenous magnetic flux distribution along the rectifying column and, secondly, to smooth electric gradient in the surface of coils of the primary winding.

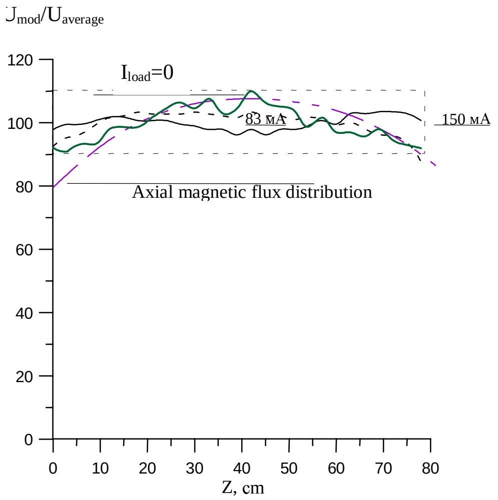

Fig. 3

As a result there are not any gradient screens presented at the primary winding that simplifies the accelerator design and improves cooling condition of insulating gas. DC voltage distribution measured along the rectifying column under total 75 DC voltage and various load currents is shown in Fig. 3. As it may be seen from the dependencies, non-homogeneity of the distribution does not exceed ±10% in a load current range from 0 to 15 mA that corresponds to 0-150 mA under operating accelerating voltage of 750 kV.

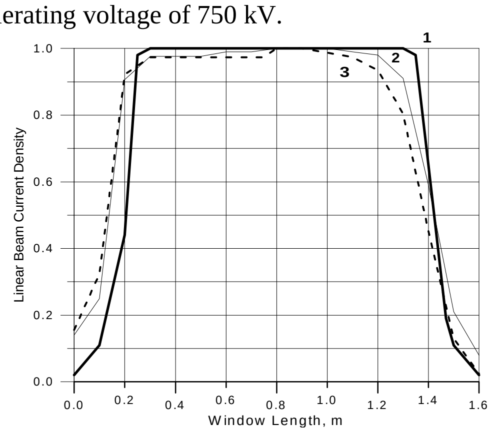

Fig. 4

1 – in accelerator with traditional triangular shaped vacuum chamber

2, 3 – in the windows of the accelerator with beam forming system with turning magnets

An accelerating tube made by the diffusion welding method and combined from the four 200 mm long sections is placed as a cantilever inside the HV generator and on the same axis with it. Resistive voltage divider for smooth potential distribution along the tube and electromagnetic screening rings decreasing the field value on tens are fastened on the outer side of the tube electrodes. An electron source with LaB6 emitter has several thousand hours lifetime.

HV generator and accelerating structure are placed in the metal 1,8 m^3 vessel filled with an insulating gas (SF_6 under 0,8 MPa or mixture of 80% of SF_6 20% of N_2 under 1,2 MPa pressure). Gas handling installation having membrane compressor performs the insulating gas re-pumping, drying and storage. It is the optional equipment to be chosen by a Customer.

Electron beam irradiation field forming system consists of magnetic lens, scanning electromagnets and two elongated turning constant electromagnets. The turning magnets due to their electron optic characteristics provide almost normal angles (90±7°) between electron trajectories and outlet window foil plane. In comparison with a typical scheme of beam scanning in a triangular vacuum chamber where those angles go up to 30°, beam loses here are sufficiently lesser but because of the beam 90° turn its size on the further side of the outlet window increases in 20-25 times and its careful focusing by the magnetic lens in this point is necessary. Linear beam current distribution along the windows is shown in Fig. 4. As it may be seen, the distribution differs very slightly from the traditional one in the triangular vacuum chamber [1]. To achieve a homogenous heat load on the foil the beam is also scanned in the cross direction. Beam scanning as well as its transfer frequency from window to window is regulated (see Table 1). Foil in the windows is pressed by an atmosphere pressure to the ribs of copper water-cooled flanges. Outlet window has about 90% transparency for electrons and does not need any air blowing for the foil cooling thus many times decreasing ozone and nitrogen oxides generation that simplifies problems of their neutralization. Processed material goes through the systems of stainless steel transporting rolls and is being irradiated consequently from one, and then from another side (see Fig. 5). Water-cooled plates capable to receive full beam power are placed on the inner side of steel-lead local radiation shielding doors, that is being necessary during the accelerator adjustment or in the case of the processed material rupture.

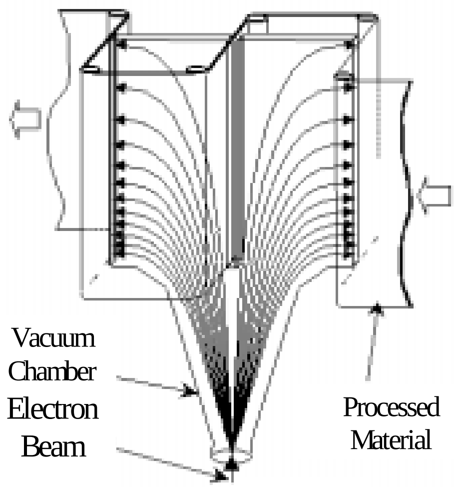

Fig. 5

Mass production thyristor frequency converter having 92-93% efficiency is used as a power supply. Total accelerator electric efficiency (without energy spent on pumping of the cooling water, that is about 4 m3 per hour) is shown in Fig. 6. Accelerator room has to be equipped with an evacuating ventilation corresponding to the sanitary rules.

Control console and two racks are placed in the accelerator control room. We are planning to equip the next similar accelerators with an automated control system on the base of industrial computer that is developed in our institute recently.

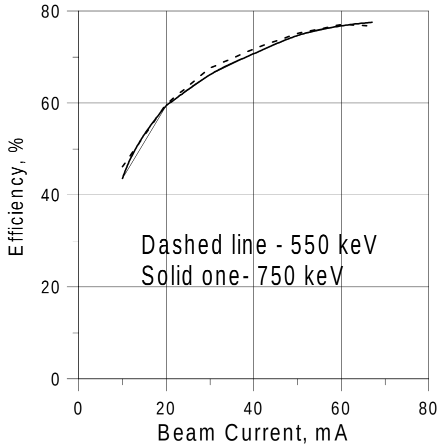

Fig. 6

There are 3 items of the “Electron-10” accelerator manufactured till now, two of them intended for the soft roofing production lines, and third one – for the foamed polyethylene production.

“Electron-10” installed in the soft roofing production line at the Ivanovo Rubber Sole Plant is displayed in Fig. 7. It is seen from the photo that the accelerator, due to its compactness, looks quite in place in the production line structure. During four years of operation it has been used as for the soft roofing manufacture as for development of some new technologies. Experience shows that the most serious problems are caused mainly by the cooling system. When the cooling water is not clear enough or the pressure changes sharply and the season temperature fluctuations occur, then the accelerator interlock system sometimes turns off the accelerator. These problems have been overcome when the autonomous water-cooling was arranged. Other problems were connected with rare but serious malfunctions of the thyristors frequency converter. In our new machines we are planning to replace it by the IGBT based power supply.

Double-windowed electron beam irradiation field shaping system with two elongated turning magnets has shown its serviceability in the industrial conditions and did not bring any unusual difficulties to the line personnel work (foil replacement, re-tuning for the irradiation field width changing).

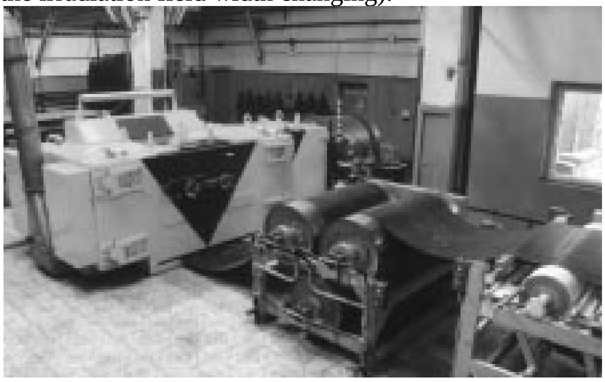

Fig. 7.

Experience gained during development of “Electron-10” accelerators, their testing and running in the industrial conditions gave necessary data to build similar to it compact, self-shielded and easy serviceable accelerators on the energies up to 1,5 MeV and the beam current up to 100 mA. It should be mentioned that the accelerator itself might be used as a good replacement of our “Aurora” type machines, which are being used in the various industrial lines for many years.

REFERENCES

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