EXTENDED SCOPE OF APLICATION OF INDUSTRIAL ELV ACCELERATOR

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Abstract

ELV accelerators are DC machines, designed and manufactured by Budker Institute of Nuclear Physics of Siberian Branch of Russian Academy of Science. These machines are well known in the world. They are operating from Germany in West to Indonesia and Malaysia in East. Main application of these accelerators is the treatment of polymers. New development of ELV accelerators is concerning the low energy range and design of self-shielded accelerators. There are the set of self-shielded accelerators. The lowest energy is 150 - 200 kV. These machines are unified with usual ELV accelerators and extend their application area. For industrial tomography based ELV4 accelerator was developed with low values of ripple current (≤2%) and the instability of energy (≤5%) of the electron beam.

INTRODUCTION

Radiation-chemical technology with the use of electron accelerators as the sources of ionizing radiation had been widely developed. Budker Institute of Nuclear Physics of the Siberian Branch of Russian Academy of Sciences is one of the world leaders in the development, design, production and delivery to the industry of electron accelerators of different types (i.e. continuous accelerators based on high-voltage rectifier, high frequency, pulse, etc.), covering a wide range of accelerated electrons energy and power. ELV accelerators hold a specific place in the range of equipment manufactured by the Institute. Compact dimensions and high operational qualities have allowed BINP take a leading position in the market of industrial accelerators, both in Russia and abroad. The ELV accelerators series has the range of accelerated electrons energy from 0.3 to 2.5 MeV, maximum beam power for separate machines from 20 to 100 kW and maximum beam current up to 100 mA. The special accelerator was designed and manufactured for ecological and research purposes with a beam power 400 kW.

DEVELOPMENT OF ELV ACCELERATORS FAMILY

ELV accelerators high voltage source is a generator with a cascade of parallel inductive links. HV rectifier column is installed inside the primary winding. The primary winding is powered by a frequency converter on the base of IGBT transistors. The secondary winding of the coil have the maximum induced voltage of about 20 kV. This voltage is rectified by voltage doubling circuit. Rectifier unit connected in series or series-parallel to form the column of HV rectifier, ending with the high-voltage electrode. The injector control unit is located inside the high-voltage electrode. Accelerator tube is placed inside the rectifier column and the top of the tube is connected with the high-voltage electrode. All these elements are placed inside the pressure vessel filled with insulating gas (SF_6). This design reduces the overall dimensions of ELV accelerators and makes them the most compact among the devices of this class. The accelerator is supplied with gas system that enables to save SF_6 gas during maintenance and repair. Vacuum systems and the extraction device are attached to the bottom of the vessel. The cathode is placed at the upper end of the accelerator tube. The electrons emitted by the cathode have the full energy at the exit of the accelerator tube. They are passing through the system of scanning magnets that evenly distribute electrons on the foil window. The electron beam is scanned in 2 directions along and across the window. The material moves under the window in the transverse direction and is treated by extracted electrons. The beam position inside window is monitoring. The accelerator control is equipped with an automated system that enables not only to make the operator's job easy, but to synchronize the process equipment and the accelerator, or combine them into one complex.

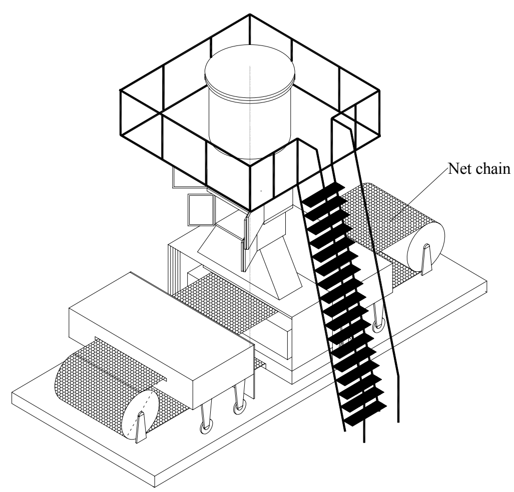

Figure1: 0.3 MeV*100 mA accelerator for tire industries.

The analysis of demands for accelerators (a market for accelerators) was made in 2011. As a result, the in-demand accelerators are distributed evenly for maximum energy from 1 MeV up to 2.5 MeV. Concerning the beam power – all queries on the boosters had 100 kW beam

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power. In accordance with the results of the analysis of ELV family was supplemented by accelerators with the maximum current up to 100 mA in the range 0.5-1.0 MeV, with max. current 80 mA in the range of 0.8-1.2 MeV, max. current 67 mA - in the range of 1.0-1.5 MeV.

For the range of energy 1.0-2.5 MeV max. current is the same as previous - 50 mA. Maximum beam power for all of the accelerators is 100 kW.

Analysis of last years' activity concludes the increasing requests of low-voltage machines (range 0.3-0.7 MeV). In all these settings, it was the wish of the local radiation protection. It should be noted that the increasing interest in low-voltage accelerators is caused by the mobile accelerators, among others. This mobile accelerator was developed together with our South Korea partner EB-TECH Co Ltd. The main purpose of this machine is to demonstrate the advantages of electron beam technology for environmental purposes (Fig. 2).

Figure 2: Mobile accelerator.

As a result of the carried out research the Institute offers a series of accelerators in the local protection of overlapping energy range of 0.25-0.7 MeV. The value of the maximum current depends on the design of the extraction devices (length of foil windows, one window, two windows) and can reach up to 150 mA.

Figure 3: Accelerator for producing of foamed polyethylene was upgrade in 2012.

The accelerator for rubber industry 0.3 MeV*100 mA is shown in Fig.1. The new concept enables to upgrade accelerators produced by other manufacturers. Figure 3 shows the accelerator which was manufactured by Efremov Electro-physical Institute (Russia) in 1970 and modernized by BINP in 2012. The exhaust system of the electron beam to the atmosphere has been remained non-upgraded, the system scans the beam was changed to the original for ELV accelerators.

UTILIZATION OF ELV ACCELERATOR FOR TOMOGRAPHY

Electron beam tomography is highly attractive as an imaging tool for technical flow studies, because it is fast and gives a good spatial resolution of one millimetre or better. Furthermore, this technology is very versatile, that is, electron beam scanning can be adapted to complex object shapes and can be extended to multi-slice and three-dimensional imaging . One particular problem associated with technical multiphase flow studies is associated with the fact that multiphase flows do often occur in vessels of complex geometries, with thicker

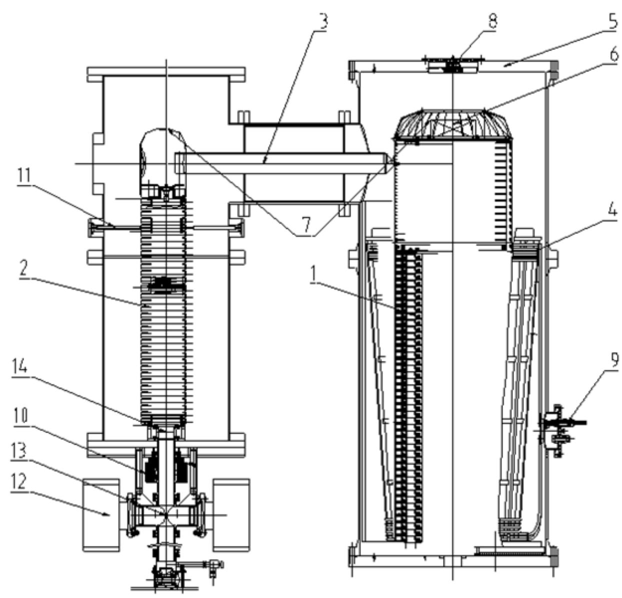

Figure 4: Common design of accelerator: Common design of accelerator: 1 - column rectifying sections; 2 - accelerating tube; 3 - gas feeder; 4 - the primary winding; 5 - the case of the pressure vessel; 6 -block injector control; 7, high voltage electrodes; 8 - the optical elements of the beam current control system; 9 entries of the primary winding; 10 - lens; 11 - supports to support tube; 12 - ion pump vacuum system; 13 - docking port of the vacuum system; 14 - bellows for fixing the accelerating tube.

metal walls and internals. Examples are pressurized pipes and reactors with steel walls, heat exchangers, rod bundles or chemical reactors with packings, stirrers, injectors, heaters, coolers and other internals. Spatial

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resolution in X-ray tomography images is mainly limited by the focal spot size of the X-ray source due to the fan-beam geometry. The permissible spot size in electron beam tomography depends on many parameters. One is the focusability of the beam, which decreases with increasing beam emittance, increasing beam current due to space charging effects and decreasing electron energy. Another limit is the permissible power density in the spot, which is determined by the melting/sublimation point of the target material, the beam power and the scanning speed. For fast scanning of several hundred meters per second focal spot speed, the main limitation comes from beam emittance, which is inherent to the accelerator design. The ELV accelerators may achieve spot sizes well below one millimeter.

If the application of ELV accelerators for radiation modification of materials related with ensuring the required level of uniformity of the radiation dose [3], the use of ELV accelerators for the tasks of industrial tomography is associated with the need to fulfill the following requirements on the parameters of the injected beam:

- energy pulsing at the level E = 1,0 MeV ≤±5%;
- current ripple at the level I_{beam} = 100 mA ≤±2%.

To solve these problems and meet the specific requirements of design-based accelerator ELV4 was developed and is now in the process of installing the accelerator for fast imaging (Fig. 4).

Figure 5: Modified accelerating tube.

To reduce the ripple current and energy, a series of experiments were conducted on a standard accelerator ELV-4 as a simplified model of the accelerator for tomography. The main difference is that the high-voltage rectifier has a lower output capacitance, and the accelerating tube is positioned within the high-voltage rectifier.

As a result, has reduced volatility in energy of up to ± 5% at a beam current of 100 mA. To reduce the ripple current divider resistances in parallel tubes were placed additional capacity (Fig. 5). It is possible to reduce the instability of current to ± 0.14%.

Currently the accelerator for industrial tomography has been assembled at the customer's site and is subjected to adjustment tests (Fig. 6).

Figure 6: Assembled accelerator for tomography.

ELV accelerators continuously adapted for use in a variety of processes of radiation in industry and can be used for research into and development of new techniques and materials by electron irradiation.

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