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# Electron beam forming system for irradiation of large diameter cylindrical products

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**Abstract**

The report describes electron beam electromagnetic forming system, which is destined for irradiation of cylindrical long goods, specifically for PE tubes 160 mm diameter. System consists of electromagnet, power supply units, beam distributions control units, etc. for use at an electron accelerator at 5 MeV and 50 kW. The particular geometry of the magnet poles and their mutual arrangement are creating an irradiation field that allows the electrons to irradiate the surface of the product close to 90°.


*Keywords:* Industrial electron accelerator; Electron beam treatment; Electromagnetic forming system

## 1. Introduction

There is nothing special about electron irradiation of simple-formed homogeneous products, but the situation is rather different if you want to irradiate cylindrical forms like polyethylene tubes for heat supply or for transport of chemically active liquids, especially in the case when the wall of the tube is only little less than the effective electron range in the tube material. Such a problem is easy to solve if the piece of tube is short enough (not more than a few meters). One could rotate the tube under the beam extraction device or organize a multi-pass irradiation process. We have made measurements to show that for 8-pass irradiation with a rotation of tube after each pass of 45°, a uniform dose distribution is obtained through the thickness of the tube material.

## 2. Objective

The problem is much more complex in the case of irradiation of long-length tubes on spool (up to hundreds meters). This demands a complex rewind system, which is not free of "twist" in most situations, but the use of an electromagnetic circular beam scanning system can solve this problem.

The electromagnetic system mentioned above is designed for working at the installation using ILU-10 industrial electron accelerator (Auslender et al., 2002). ILU-10 has the following main parameters: electron beam energy: 3.5–5.0 MeV, average beam current: 14–10 mA, beam power at the full energy range—50 kW. The concept of the beam scanning system is shown in Fig. 1. First the beam is scanned by the normal beam scanning system (Fig. 1, pos. 2), and then beam is going to the circular beam scanning system.

The calculated beam paths inside and outside of the normal beam scanning device of the accelerator are shown in Fig. 2, together with the beam paths inside the circular beam scanning system. To receive such form of beam paths the variable-polarity magnet field in pole gap must have a special form like the one shown in Fig. 3. We have obtained such field by a smoothly changing of pole gap from the center to the edge of the electromagnet. The size of electromagnet in the $Y$-direction depends on the maximum tube diameter. The size of magnetic field in the $Z$-direction is determined by the necessary radius of the extreme beam paths and it is near 40 cm. The best dose uniformity will be obtained when the angle to the surface of the incoming electrons is close to 90°.

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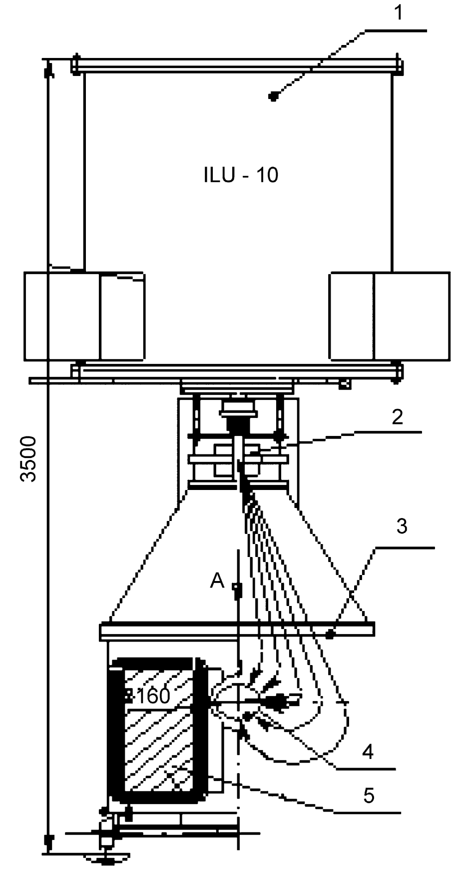


Fig. 1. The concept of beam scanning system. 1—accelerator ILU-10, 2—ILU-10 beam scanning magnet, 3—beam extraction device, 4—tube to be irradiate, 5—electromagnetic circular beam scanning system.

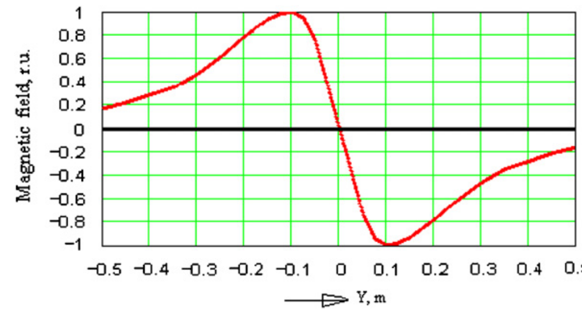


Fig. 3. Necessary magnet field in pole gap.

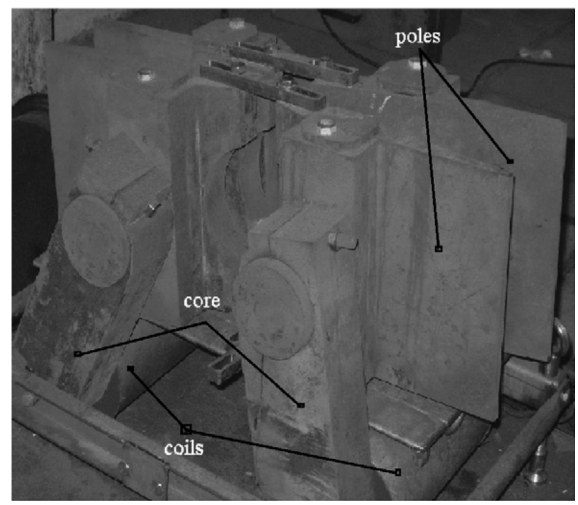


Fig. 4. The prototype of electromagnetic forming system.

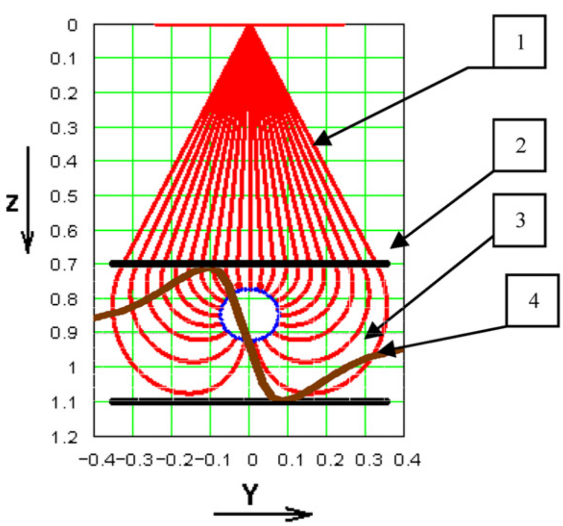


Fig. 2. Calculated beam paths (pos. 1) before beam extraction device (schematically pos. 2). Beam paths inside circular beam scanning system (schematically pos. 3) and form of magnetic field (pos. 4).

The range of the 5-MeV electrons is approximately 27 mm in the tube material and tubes with wall thickness up to 20 mm can then be treated with acceptable dose uniformity.

## 3. Experimental

To check the theoretical calculations and to prove the principal opportunity of irradiation of cylindrical goods, the prototype of circular beam scanning system was used (see Fig. 4). This magnet was originally designed for only 3.0 MeV electrons from an ELV-type accelerator (Veis et al., 2002) and it had circular-form poles. We have changed the form of the poles to be rectangular and decreased the pole gap to 15 mm in the center and 50 mm at the edge to obtain the necessary magnet field flux for turning 5.0 MeV electrons. Such values of the gap is insufficient in practice, because the beam is naturally enlarged as it passes through the air gap between the extraction device and electromagnet and inside the electromagnet, so a part of beam was lost on the poles. However, limitations of coils and core of the prototype did not allow the necessary pole gap of 150 mm in the center and 500 mm on the edge.

The results of irradiation of 160 mm diameter polyethylene tube with wall thickness of 14.5 mm are shown in Fig. 5. One can see the good azimuth dose distributions in the different layers of the irradiated tube. Doses were measured by B3000 film dosimeters produced by GEX

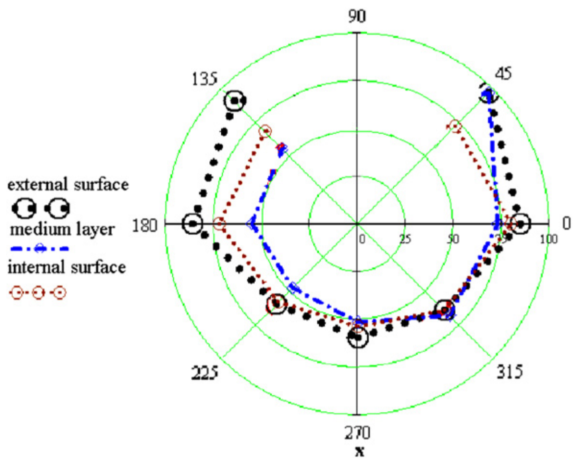


Fig. 5. Dose distribution in the PE tube160 mm diameter. Wall thickness of the tube is 14.5 mm.

Corp. To measure dose distribution on medium layer, film dosimeters were placed at very narrow circular chink turned in the wall of tube. For the reasons mentioned above (insufficient gap size), the doses at sector 45–135° were several times higher than the bottom. The situation will be solved if a 150 mm pole gap is used.

## 4. Results

Our experiments at prototype showed that the principle of irradiation of long-length PE tubes is possible. To receive best dose distribution, the working version of electromagnetic forming system must have a pole gap not less 200 mm to avoid beam losses inside of the magnet. This system is now being designed.

The number of needed ampere-turns in the magnet is $1 \times 10^5$, magnetic field flux is 2000 G and the power consumption is 4.0 kW; the weight of the system is about 4.0 t. The system is intended for 3.5–5.0 MeV electron beam and beam power could be up to 50 kW. The system is flexible and easy to adjust for functioning with any kind of cylindrical products having diameter from 80 to 160 mm.

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