Development of a compact electron accelerator for livestock odor treatment

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1. Introduction

Electron accelerators are utilized in various industrial fields, including medical applications. Industrial electron accelerators of this kind typically generate electron beams with energies within 10 MeV and powers ranging from tens to hundreds of kW. Currently, KAERI is developing a compact electron accelerator system to reduce livestock odor using an electron beam.

Generally, Direct Current (DC) type electron accelerators are used for industrial gas treatment. However, since DC accelerators are large and heavy, they are primarily used in fixed facilities, which poses significant limitations for use in diverse user conditions. To address this issue, a pulsed electron accelerator was introduced to miniaturize the accelerator system. The developed system generates an electron beam with a beam energy of 500 keV and a beam current of 1 mA, driven by radiofrequency (RF) power. The entire system, including the gas reactor, radiation shielding, and auxiliary devices, is installed in a space of approximately 2.5 m (H) × 2.5 m (W) × 4 m (L) and weighs about 8 tons. This paper describes the details of the electron accelerator system under development.

2. Livestock odor treatment system

The integrated livestock odor treatment system is designed to reduce and eliminate a variety of high-concentration odors produced in livestock facilities. It consists of an electron accelerator of which power is controlled by an odor sensor, a gas reactor, and a biofilter based on a porous carrier containing radiation-resistant microorganisms.

The system's key components, the electron accelerator and the gas reactor, including their shielding, are modularized and designed to be mounted on a vehicle. This makes the system mobile and adaptable for use in various locations.

Figure 1. Configuration of the integrated livestock odor treatment system.

3. Electron accelerator

The electron accelerator uses a widely-used industrial S-band RF accelerating cavity, allowing for research into odor decomposition using a pulsed electron beam. It is designed with a 2.5-cell standing-wave structure to ensure stable electron beam acceleration even with a possibility of RF power shortage. The accelerator generates a 500 keV electron beam at 1 mA (with a maximum of 3 mA).

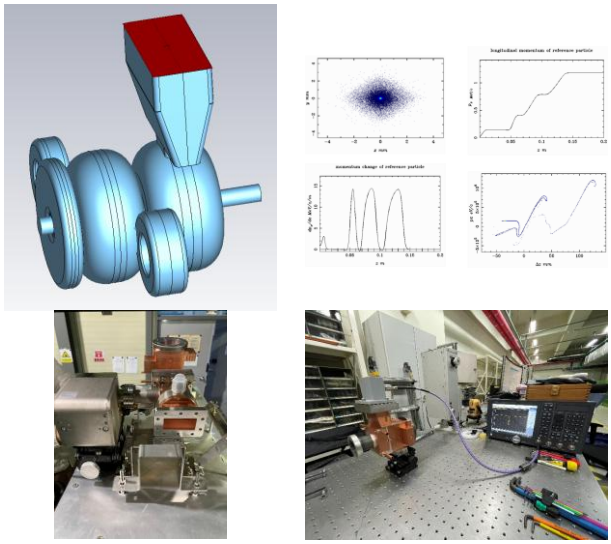

Figure 2. 3D modeling of the RF cavity (upper left), beam dynamics simulation results (upper right), fabricated RF cavity (bottom left and right)

Control system of the accelerator is configured to increase operational efficiency by providing real-time feedback on odor volume and concentration, which in turn controls the electron beam output.

4. Compact accelerator module mounted on a vehicle

4.1. Modularization of the electron accelerator system and the vehicle it is mounted

To enable immediate mounting onto a vehicle, the system was designed as a modular unit. It integrates the core components—including the RF power source (modulator, magnetron), electron gun, accelerating

cavity, and RF transmission components—with auxiliary systems like vacuum, cooling, electric power, signal generation, and controls.

The vehicle designed to transport the electron accelerator module offers a protective environment for the equipment while ensuring easy maintenance for the user through a thoughtful internal layout and multiple access points. It also includes an air conditioning system to prevent malfunctions and premature aging of the accelerator, which is sensitive to environmental changes. An interlock system is built in to protect both users and the equipment during operation.

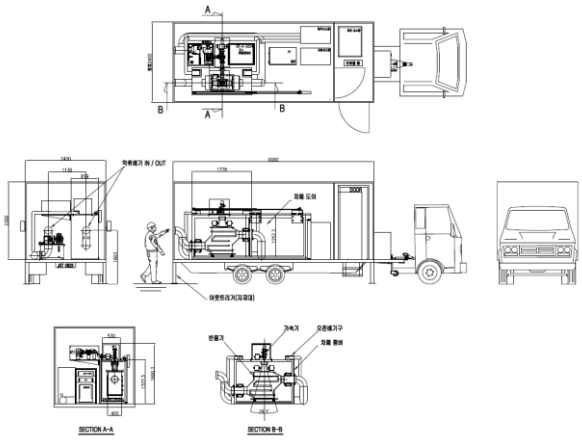

Figure 3. Layout of the accelerator system mounted on a vehicle

Figure 4. Equipments installed in the vehicle

4.2. Radiation shielding

The shielding for the electron accelerator is designed to completely enclose the electron gun, accelerating cavity, scanning horn, and gas reactor surrounding in all six directions. To minimize the weight of the self-shielding accelerator module, different shield thicknesses were adopted depending on the location. Additionally, a special shielding structure was applied to all parts that penetrate the shield, from the inside to the outside due to cooling channels and power cables.

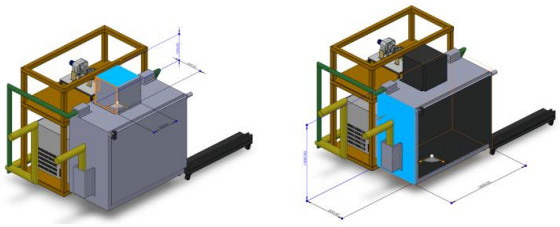

Figure 5. Design of the shielding module for the electron accelerator

5. Summary

To facilitate the direct use of electron accelerators at sites where electron beams are applied, a mobile, compact electron accelerator system was built. This device is scheduled to be deployed to a livestock facility in the second half of 2025 for a demonstration study on its effectiveness in reducing odors.

This compact accelerator was developed based on existing research at the Radiation Equipment Fabrication Center. It is planned to be optimized and improved for broader application in environmental and military defense fields.