DESIGN, SIMULATION AND COMPARISON OF ELECTROSTATIC ACCELERATING TUBES FOR A 1MeV PARALLEL FEED COCKCROFT-WALTON INDUSTRIAL ACCELERATOR

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Abstract

In this article accelerating tubes whit different geometries and different constructions are designed and simulated for a 1 MeV parallel feed Cockcroft-Walton electrostatic industrial accelerator. Simulations are carried out using CST Particle Studio. The accelerating tubes with different electrode geometries are designed and simulated and compared with each other. Finally whit respect to the comparisons the best geometry is selected. In this tube a 1 MV DC voltage is applied at several stages during the accelerating electrodes. Maximum electron beam current in the tube is 200 mA. In this application accelerating electrodes and focusing electrodes are stainless steel and insulators between electrodes are Borosilicate glass.

INTRODUCTION

Accelerating tube roll of an electrostatic accelerator is voltage dividing in a strait section to accelerate the particles gradually. By applying electric field between tow electrodes, charged particles can accelerate in the gap between tow electrodes. If the applied voltage gradually raises, finally causes spark in the gap of tow electrodes. Therefore if we need to upper voltages, we should eliminate this problem with appalling high voltage in several electrodes gradually instead of tow electrodes. This method also allow us to use some electrodes as focus elements to adjust beam shape and beam dynamics. The array of electrodes, instead of tow electrodes also make a more uniform electric field in the accelerating tube and it causes fewer particle loss in tube.

The electric field between the electrodes calculate from equation (1)

$$E=-\nabla V \qquad (1)$$

In this equation V is voltage between the electrodes. If V bee constant and without ripple thus electric field will be uniform and without the least ripple during the accelerating tube [1]. Every Electrostatic accelerating tube has three parts, the electrodes, insulator and voltage divider.

TUBE COMPONENTS

Electrodes

Electrodes create a gradient of electric field to accelerate the charge particles. In most of electrostatic electrodes the electrodes are being made from three types of aluminium, titanium and stainless steel.

Insulators

Insulators are one of the main parts of accelerating tubes in electrostatic accelerators and should have a high dielectric constant and high ability to keep the vacuum. The insulators with the higher dielectric capability can withstand more electric field gradient. Therefore we can reach to a more electric field density in a shorter distance and provide the particles with more energy in the same distance. Most used insulators in electrostatic accelerators are glass and ceramic [2]. In our tube we want to use of borosilicate glass as insulator. This type of the glass has higher dielectric constant, more ability to keep the vacuum of the tube, transparency and lesser secondary Diffusion coefficient against the ceramic.

SIMULATION WITH CST PARTICLE STUDIO

After selecting of the components of our tube, now we should design and simulate our intended tube before fabricating it. To transport the particles from the gun to end of the accelerating tube we should have a suitable potential array. For this purpose, we have several focus electrodes in the first of accelerating tube.

Focus Electrodes

The focus electrodes are in front of the accelerating tube and usually have a variable potential. In our designed tube, the first and the second electrodes are focus electrodes.

The Shape of the Focus electrodes is different from other electrodes. This difference is because of the different rolls of focus electrodes and accelerating electrodes. Figure 1 shows the first section of our tube including insulators and focus electrodes.

The first part of the tube, is being mounted on the electron gun and its potential is equal with anode potential. Its inlet radius is 10mm and its outlet slope is 45° and its length from inlet to outlet is 46mm.

The first focus electrode inlet aperture is after the first part of the tube with radius of 20mm and its outlet is 26mm. the slope of bended edge in front is 45° and its length from inlet to outlet is 40mm.

The second focus electrode is also for adjusting the shape of electron beam in the tube. In our design this electrode is designed so that simultaneously adjust the

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beam shape and keep the insulators from particle collisions. Also this electrode inlet radius is 40mm and its outlet radius is 20mm. its length from inlet to outlet is 37mm and the outlet of the first focus electrode is entered 2mm into the inlet of our second focus electrode to keep the insulator from the probable particle collisions.

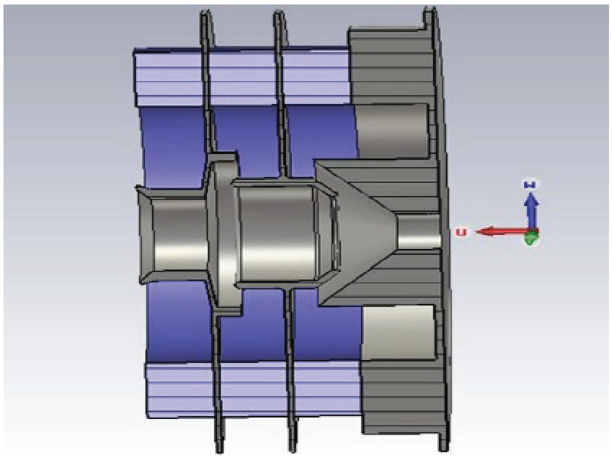

Figure 1: First section of our tube.

Accelerating Electrodes

In this article we discuss about three types of accelerating tubes with different geometries. These electrodes are designed so that keep the insulators from particle collisions and also make a good electric field in the tube for accelerating the particles from the first to end of the tube.

Figure 2 shows different accelerating electrodes.

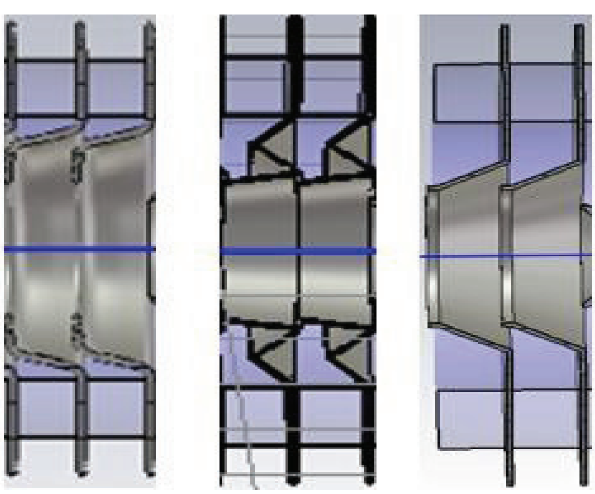

Figure 2: Different accelerating electrodes.

In all geometries outlet radius is 35mm but their inlet radius are different. In the right and left geometries, electric field is more uniform than middle geometry. Because of sharp points in middle geometries this model is more talented to makes spark in high difference potentials.

Figure 3 shows the tubes with different accelerating electrodes.

In all geometries we apply equal potential step between the accelerating electrodes and the step potential is 35KV also our focus electrodes have variable potentials. To gain the favor energy (1 MeV) at the end of accelerating tube we have 29 accelerating electrodes, 2 focus electrodes and a single part in the beginning of the tube to be mounted onto the anode of electron gun. The latest accelerating electrode is grounded and the next electrode has -35KV potential and with increasing the potential with this step the second accelerating electrode has -945KV potential but in our design the first accelerating electrode doesn't follow this process and has -965KV potential instead of -980KV. The first part of the tube has -995KV potential and is mounted to the anode. Then the anode of our gun has the same potential and cathode of the gun has -1 MeV potential. Suitable information about our designed gun is reported in [3].

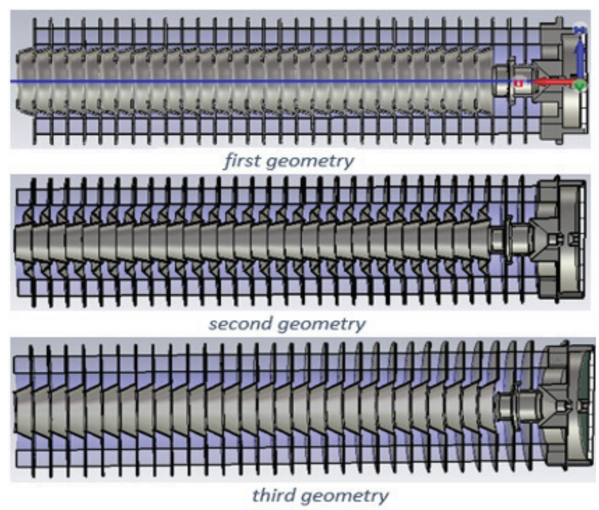

Figure 3: Different accelerating tubes with different accelerating electrodes.

Table 1 shows variations of beam radius at the end of (first geometry of) accelerating tube. The Length of our tube in all geometries is 1 meter.

Table 1: Variations of Beam Radius at the End of Tube (First Geometry) Via Focus Electrode Potential Variations

First focus electrode potential(kV)	second focus electrode potential(kV)	Beam radius at the end of tube(mm)
-995	-985	4
-990	-980	6
-985	-975	7
-980	-970	9
-975	-965	13

According to table 1 information, variations of the Beam radius at the end of tube is low and the maximum radius is 13mm when the First focus electrode potential is

-975kV and the second focus electrode potential is -965kV.

Also Figure 4 shows the trajectory of particles in this geometry. This geometry has been used in 3MeV van de Graaff accelerator of Iran atomic energy agency.

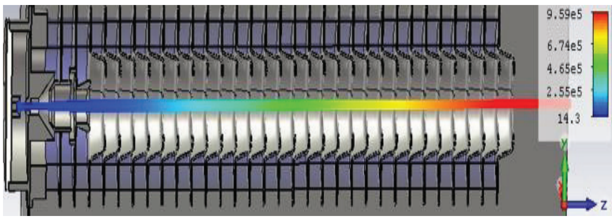

Figure 4: Trajectory of particles in the first geometry.

The second geometry is rarely being used and has more complex structure therefore its electric field distribution is not as uniform as another geometries. Table 2 shows the variations of beam radius at the end of this tube.

Table 2: Variations of Beam Radius at the End of Tube (Second Geometry) via Focus Electrode Potential Variations

First focus electrode potential(kV)	second focus electrode potential(kV)	Beam radius at the end of tube(mm)
-995	-985	2
-990	-980	4
-985	-975	6
-980	-970	9
-975	-965	11

According to table 2 information, variations of the Beam radius at the end of tube is low and the maximum radius is 11mm when the First focus electrode potential is -975kV and the second focus electrode potential is -965kV. Figure 5 shows the trajectory of particles in the second geometry.

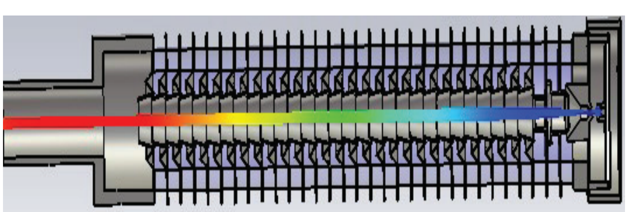

Figure 5: Trajectory of particles in the second geometry.

The third geometry is the simplest geometry and is widely being used for accelerating tubes. This geometry has been used in several Cockcroft-Walton electrostatic accelerators with energies of 150 to 200 Kev in Iran. Our electric field distribution in this geometry is uniform and probability of sparking between the electrodes is not very much. Table 3 shows the variations of beam radius at the end of this tube (third geometry).

Table 3: Variations of Beam Radius at the End of Tube (Third Geometry) Via Focus Electrode Potential Variations

First focus electrode potential(kV)	second focus electrode potential(kV)	Beam radius at the end of tube(mm)
-995	-985	2
-990	-980	3
-985	-975	3.5
-980	-970	5
-975	-965	6

According to table 3 information, variations of the Beam radius at the end of tube is low and the maximum radius is 6mm when the First focus electrode potential is -975kV and the second focus electrode potential is -965kV. Also Figure 6 shows the trajectory of particles in this geometry (third geometry).

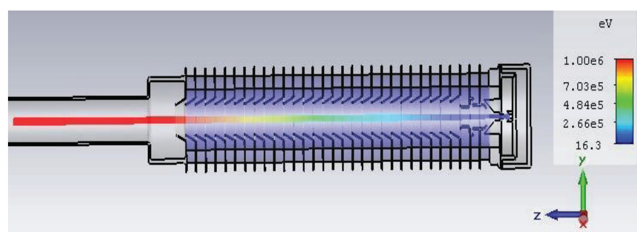

Figure 6: Trajectory of particles in the third geometry.

CONCLUSIONS

Several different geometries can be used for electrostatic accelerators tube. Every one of these geometries has almost the same result but they has different costs of constructing and different life times (depend on different materials). As has been shown in all geometries when the first and the second focus electrodes potentials are near to anode of our gun beam waist radius at the end of tube is low and the beam is focused but when these potentials decrease and the difference potential of focus electrodes and the anode is up our beam waist radius at the end of tube raises. Also we see that the first geometry has the most beam waist radius (13mm) and the third geometry has the least beam waist radius (6mm).

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