Chapter 7

Electron gun for Compact Baggage Scanners

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Baggage scanners are widely used for scanning luggage at airports and various locations of strategic importance. The threat of terrorist attacks and increasing crime rates has increased the demand for compact baggage scanners. Any baggage scanner in principal is composed of three components, X-ray source, image generation and baggage guiding system inside and outside of the scanner. All the technologies except electron beam based X-ray source are indigenously available. The electron beam based X-ray source consists of electron gun and tungsten target. The electron gun is based upon thermionic emission and is made from tungsten wire.

7.1 Description of Electron Gun

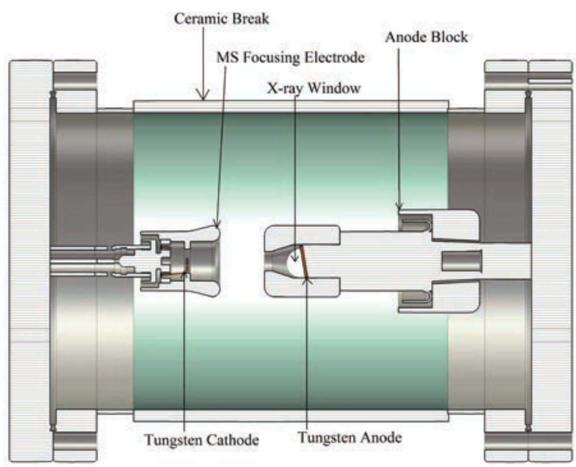

Figure 7.1: 3D schematic of electron gun used for modelling.

In the electron gun design, a tungsten spiral cathode is simulated for electron beam emission and tracking of emitted electron paths [26]. The simulation has been done is CST Particle Tracking Solver. The simulated structure is shown in Fig. 7.1. The whole structure is 150.0 mm long. Both ends of the glass tube are having DN 35CF flanges weld to them. The structure will be in active pumping in the initial stage by the DN 16CF flange welded at the right end of the tube. The electron gun to be designed operates in thermally limited region as the required beam current is 2 mA, which is very low [27]. The applied voltage can be varied from 80 kV to 160 kV. The heater of the electron gun will operate at 10 V, 1 A electrical parameters.

7.2 Simulation of Electron Gun

The electron gun was simulated in CST Particle Tracking Solver [28, 29]. The electron gun has various components which require differential meshing to optimize the simulation results while minimizing the simulation time. The meshing of the electron gun is shown in Fig. 7.2. Tetrahedral meshes are used for structure discretization owing to better representation of the geometry. A high voltage of -40 kV is applied on the cathode and +40 kV is applied on anode. The distribution of electric field as obtained from electrostatic solver is shown in Fig. 7.3. The electric field peaks at the focussing electrodes and attains a value which is

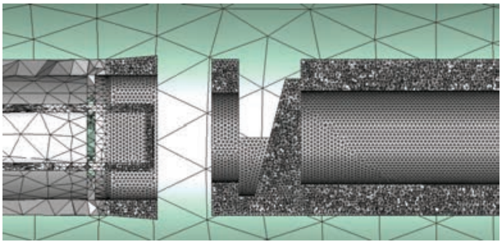

Figure 7.2: Discretization of electron gun with tetrahedral meshing.

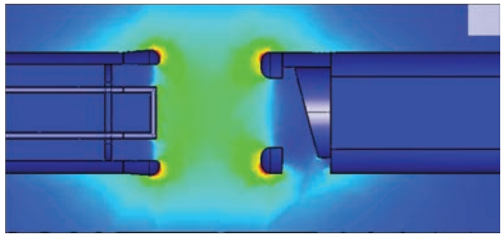

Figure 7.3: Electric field stress on metallic surfaces for 160 kV potential difference between anode and cathode.

lower than the vacuum breakdown threshold value of 100 kV/cm. The peak electric field is 98 kV/cm at the outer surface of focussing electrode. The structure is subjected to particle tracking solver for observing the emission current and track of electron beam at 160 kV accelerating voltage. Thermionic emission model has been used for electron beam generation from tungsten cathode. The annular tungsten wire cathode has been simplified into a solid cathode having 1.0 mm diameter for simplicity. There is a 17.0 mm gap between anode and cathode. Though we are utilizing thermally limited flow but still it is better to know

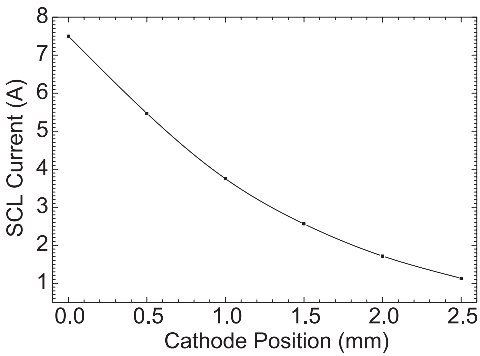

Figure 7.4: Variation of maximum space charge limited (SCL) current with cathode position.

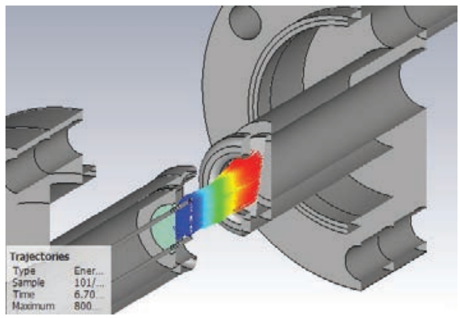

Figure 7.5: The beam trajectory for 2.0 mA electron beam current and 1.0 mm separation between cathode and focussing electrode.

the maximum current that is supported by geometry. The relative position of cathode with respect to focussing electrode governs the maximum electron beam current achievable for the given geometry for a given anode cathode voltage. The variation of the space charge limited current versus relative position of cathode is plotted in Fig. 7.4. It may be seen that with cathode going inside focussing electrode space charge limited current is getting reduced but focussing of electron beam gets better. We simulate the structure for thermionic emission giving cathode a temperature of 2000 K. The work function of the cathode is kept to be 4.5 eV. The track of the electron beam is shown in Fig. 7.5 for 2 mA electron beam current.

7.3 Conclusion

A thermionic electron gun capable of providing 2.0 mA electron beam current for a 160 kV potential difference between anode and cathode has been designed for compact indigenous baggage scanners. The simulations done at 2000 K reveal that in order to achieve the required current we have to use tungsten wires having 0.1 mm to 0.2 mm diameter and make spiral shape of it so that effective emission area of the cathode may be increased.