DESIGN AND SIMULATION OF SIDE COUPLED SIX MEV LINAC FOR X-RAY CARGO INSPECTION

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Abstract

Using in X-ray cargo inspection is one of the most important applications of linear accelerators. This paper represents design and simulation of Side Coupled Six MeV cavities. The electromagnetic simulation of structure was carried out in the SUPERFISH and CST Microwave studio. 2.3 MW input power is considered according to MG5193 magnetron. The coupling coefficient calculated equal to 3% for stabilization of accelerator operation against environmental and mechanical errors variations.

INTRODUCTION

Nowadays, detection of explosives, weapons, and radioactive material has a higher priority than other uses. The cargo inspection systems can be designed based on different physical principles that the most important of them is the use of neutron and X-ray. Cargo scanning system consists of an electron accelerator, a target of bremsstrahlung radiation generation, and an array of detectors. Such system with the electron beam works in the energy range of 3-9 MeV and provides the opportunity to take photographs from the contents of containers [1, 2]. In the third method, the high-energy X-rays penetrable are used in the dense cargo containers [1]. The single-energy X-ray transmission method is relatively simpler and less costly than other methods. According to the recent studies, linear accelerator cavity has been designed of side coupled type to access 6 MeV and 75 mA output electron beam and current, respectively. This design provides conditions that the system can investigate the various types of cargos, and so can be easily moved from one place to another by using a magnetron generator.

MATERIAL AND METHODS

In this study, the side-coupled standing wave structure is selected for our systems. S-Band structures are more accessibility and reasonable construction size in Iran as a first experience. Also, the operation frequency is selected of 2997.92 MHz [3]. The required electron beam current was considered to be about 75 mA for the desired system. Accelerator cavity design steps are: first, design and optimization of the acceleration cavity components; Second, coupling cavity design; Third, optimized cavity design by the three-dimensional code for the estimation of mesh size; Fourth, full design included a three-cavity coupling and the cavity acceleration; Fifth, the design of a complete set of acceleration and coupling cavity with length of 45 cm [4, 5]. The most common type is the nose cone which has two radial. Different sample design is shown in Fig 1. Simulated coupling cavity is shown in Fig 2.a based on the calculation, the parameters in Table 1, and the second geometry in Fig 1.

Figure 2.b shows half geometry of an acceleration cell with its geometric parameters in SUPERFISH code [7]. Figure 3.a and 3.b shows the designed geometry in the CST code with the obtained profiles of field.

This method uses of two the CST and the SUPERFISH code simultaneously. The process used in this design is as follows.

1- Optimized geometry of the coupling and acceleration cells for resonation is calculated and designed by the two-dimensional SUPERFISH code in the frequency of 2997.92 (MHz).

2- After optimization by SUPERFISH code, the obtained geometry optimized by the CST code again. Also, the resonant frequency of the coupling and acceleration cavities that they are fc and fa, respectively is calculated.

3- Geometry simulation of the two half-acceleration and one coupling cavity is done by the CST.

4- Again, the coupling and acceleration cell are designed for resonance by the SUPERFISH code in the frequencies of 2997.92+ Δfc and 2997.92+ Δfa, respectively.

5- Steps 2 and 3 are repeated for the new dimension of the SUPERFISH Code.

6- The resonant frequencies and coupling constants are recalculated [9].

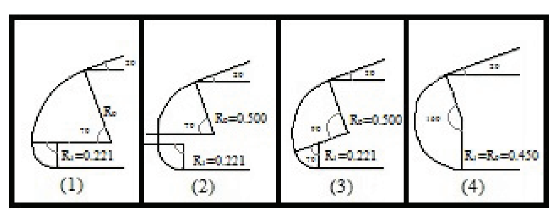

Figure 1: The usable nose cones in the design of standing wave cavities [8].

Table 1: Accelerator Operating Parameters

Basic design parameters	Selective values
Frequency (MHz)	2997.92
Total available microwave power (Mw)	2.3
Final energy of the output beam (MeV)	6
Cavity length (m)	0.45
Peak current of output electron beam (mA)	75
Effective shunt impedance (MΩ/M)	53

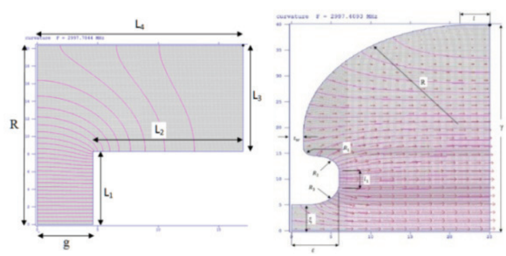

Figure2:a) Simulated coupling cavity by SUPERFISH Code, b) Half geometry of an acceleration cell with its geometric parameters in SUPERFISH Code.

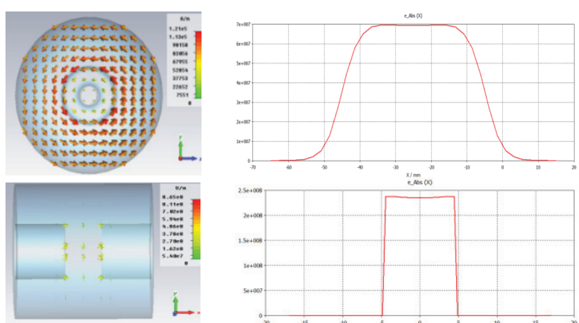

Figure 3:a) the acceleration cavity and its electric field curve. b) Coupling cavity and its electric field curve

RESULTS

According to the results, the coupling and acceleration cavity should be designed to the resonant frequency of 3109.44 and 3022.9 MHz, respectively. In this case, the first order coupling among neighbor cells was achieved 3.5 percent. The final dimensions of the coupling and acceleration cavities are calculated and reported in Table 2 and 3. Also, Fig 4 shows the two-dimensional view of the resonant field for the mode of zero, π/2, and π. After completing the previous design, total structure of the accelerator tube contained 9-acceleration and 8-coupling cells are evaluated at the end of the stage. After the simulation by the CST code, the electric and magnetic fields are calculated for mode of π/2. Figure 4 shows the geometry of the cavities. Electric field vector in mode of π/2 is shown in the Fig 5. Also, in Fig 6 - A, B and C, the electric field diagram are shown for the three oscillatory modes in zero, π/2, and π.

The field diagram shows that tail-ends of the acceleration cavity are well excited. Figure 7 shows the dispersion curves obtained from the simulation. This curve confirms the fact that the band gaps width increases due to lack of the exact match in frequency.

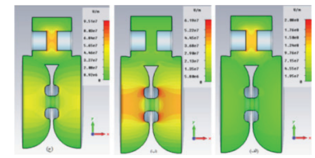

Figure 4: The two-dimensional profile of resonate field for the modes of 0, π/2, π.

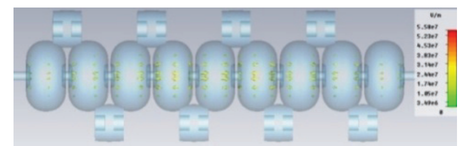

Figure 5: Electric field vectors to mode of π/2.

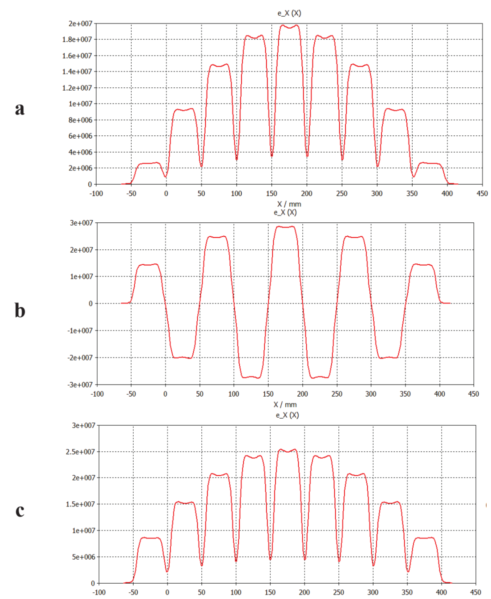

Figure 6: Electric field in the mode of a) zero, b) π/2, and c) π.

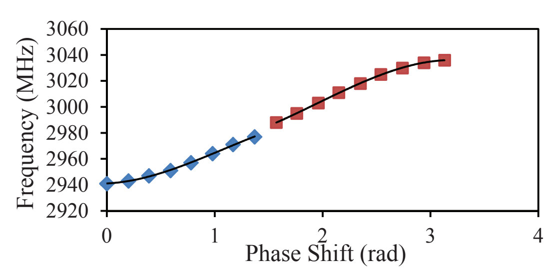

Figure 7: The dispersion curves obtained from the simulation.

CONCLUSION

As shown in Fig 7, despite simulation errors you can rely to the software results based on the number resonant modes. The coupling coefficient of the curve is at about 0.037 percent. In this case, the resonant mode is about

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2991 MHz. Nevertheless, the final results in the field shape of the acceleration tube structure match with the resonance in the mode of π/2. Also, the symmetry of two branches in the curve has appropriate symmetry. However, you should be had more precise simulations and measurements from a sample of made three-cavity. The frequency interval is reduced in the mode of zero and π. These data directly indicate the difficulty of designing and building side-coupled standing wave cavities in mode of π.

Table2: Final Dimensions of the Acceleration Cavity (mm)

γ	L	L_1	R	R_1	R_2	R_3	t_w	ξ	ε
39.65	2.5	2	21	2.1	2.5	3.4	1.5	5	6.1

Table3: Final Dimensions of the Coupling Cavity (mm)

L_1	g	R	L_4
39.65	2.5	2	21

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