DESIGN AND CONSTRUCTION OF BRAZED SIDE COUPLED CAVITY OF MEDICAL ACCELERATOR

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Abstract

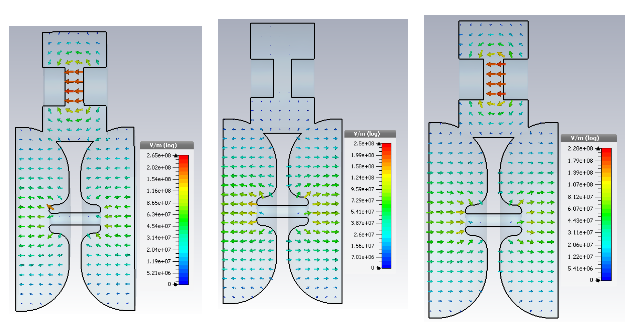
Two types of standing wave RF cavities are used routinely in construction of medical linear accelerators. These two types are Side coupled and on-axis coupled standing wave cavities. This selection is based on higher shunt impedance and compactness in comparison to travelling wave RF cavities. In this paper, we present the simulation, construction and measurement results of brazed section of 3 GHz side coupled RF cavity. It is the first successful experience of its kind in Iran. The obtained experiences can be used effectively for construction of side coupled thermionic RF guns and RF cavities of medical or industrial linacs.

INTRODUCTION

Linear electron accelerators are designed in various types and have wide applications in medicine, industry, agriculture and physics researches [1-2]. Standing wave RF cavities are so attractive for applications with emphasizes on compactness, portability and low weight to be applicable in portable industrial and rotatable medical accelerators [3-4]. Based on applications, they are constructed in X, C and S bands with energy adjustment range 4-15 MeV for industrial radiography and 4-25 MeV for cancer treatment linacs [5-6]. Because of higher required machining and assembling accuracy and larger number of parts, construction of side coupled linacs is a bit complicated and expensive than on axis coupled structures. Construction of accelerator cavities involved with many steps of high precision machining, pre-tuning, cleaning, assembling and joining with brazing or electron/laser welding, tuning and RF measurements, conditioning and high power commissioning and beam or radiation based measurements [7]. Iranian scientific societies are strongly interested for construction of particle accelerators and development of their applications and start wide activities in private companies and governmental scientific organisations to develop required technologies and necessities for this goal. The simulation, construction and Measurement results of brazed section of S-band accelerating cavity are presented in this paper.

DESIGN AND SIMULATION

The side coupled standing wave RF cavities are biperiodic configurations that are made up of accelerating and coupling cells. The acceleration of electron beam in RF cavities was done by forcing of them in electric field of accelerating cells and electromagnetic coupling between accelerating cells provided by electric or magnetic coupling holes via coupling cells. The acceleration gradient in standing wave medical and industrial RF cavities is in the range of 12 to 20 MV per meter. The simulation of side coupled RF cavities was done in two main steps that is included: (1) selection of geometrical parameters of coupling and accelerating cells for resonating in required frequency with necessary quality factor and shunt impedance (2) joining them in such a way to reach the required coupling between all of cells. The simulation of basic units with two half accelerating and one coupling cells was done by SUPERFISH [8] and CST Studio Suit [9]. The simulation results of CST were shown in figure 1-(a), 1-(b), 1-(c) for electric field profiles of 0, π/2, π modes and in figure 2 for dispersion curve of resonant modes. Also, simulation results expected from tuned structure measurement represented in figure 3. This cavity will be operated in 2998 MHz with quality factor of 14000 and effective shunt impedance of 120 MΩ/m.



(a) (b) (c)

Figure 1: Electric field profiles of 0, π/2, π modes.

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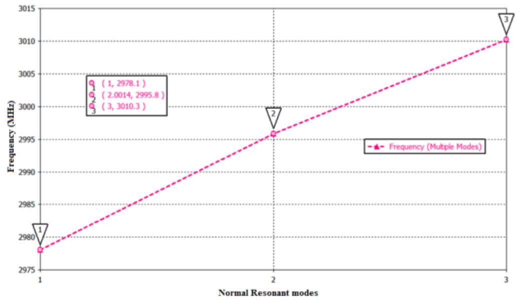

Figure 2: resonant frequency of normal modes.

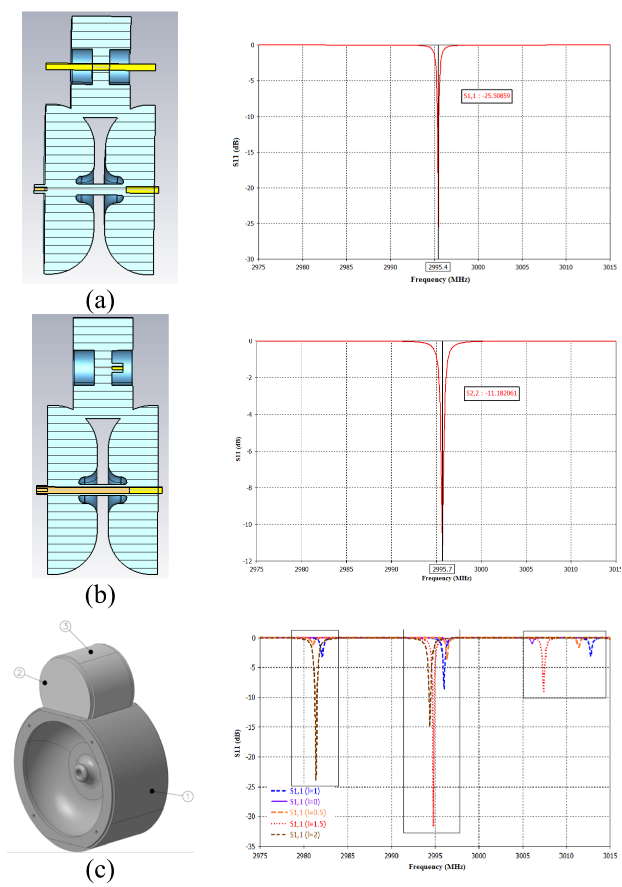

Figure 3: Simulation of expected results of measurement and tuning (a) tuning of accelerating half cells (b) tuning of coupling cell (c) frequency spectrum after tuning with different Antenna penetration Length (best on 1.5 mm).

CONSTRUCTION, TUNING AND MEASUREMENTS

After high precision machining of components and their metrology and error corrections, the brazing of components was done inside a vacuum furnace. RF cavities are composed of several components with different materials. The materials commonly used are OFHC copper, Stainless steel (304, 316), and ceramics with RF and high voltage grades. Several pins was foreseen on cavity wall to provide possibility for pulling (pushing) the walls of cells for decreasing (increasing) resonant frequency in the tuning. The schematic of components after brazing and tuning mechanism were shown in the figure 4.

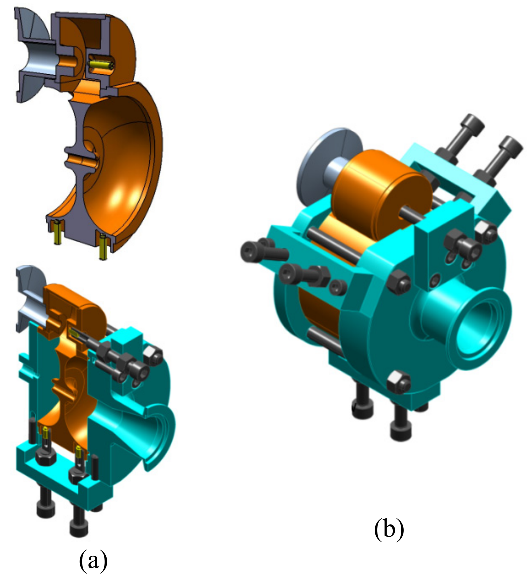

Figure 4: schematics of cavity with tuning mechanism (a) Cut view (b) Full view.

For evaluation of brazing quality in joints of stainless steel with copper and copper with copper, we designed prototype with SST flange and copper body. The first step of brazing was done for joining of coupling cell copper parts and stainless steel flange with coupling cell. Then, coupling cell was brazed to axial accelerating cells. The brazed coupling cell and whole of parts for final brazing were shown in figure 5-(a) and 5-(b) respectively. The leak result of 3×10^{-10} mbar measured by helium leak detector. Also, vacuum level improved up to 5×10^{-8} mbar after baking of coupling cell. The vacuum baking with pressure level was shown in the figure 6. The final brazed prototype with tuning mechanism was shown in figure 7. The axial field profile by bead pull measurement and frequency spectrum results of VNA are represented in Figures 8-(a) and 8-(b) respectively.

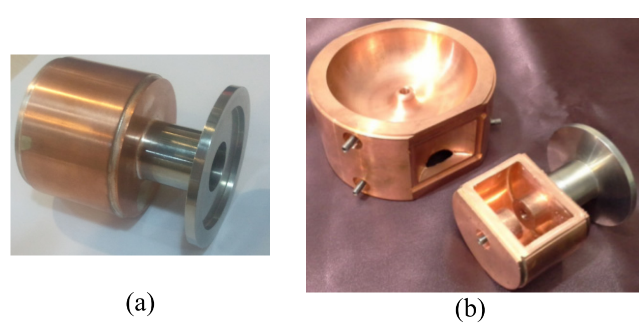

Figure 5: (a) Brazed coupling cell (b) whole of parts for final brazing.

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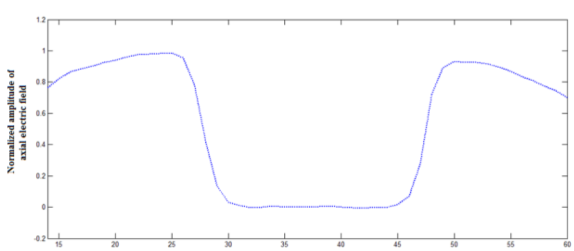
(a)

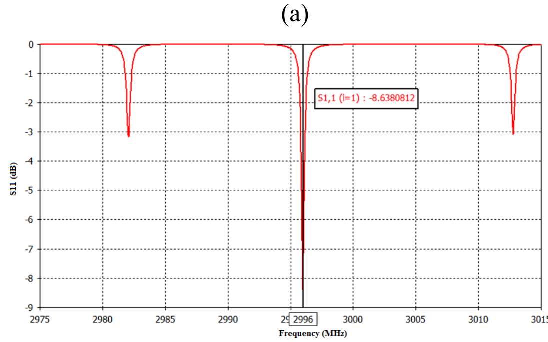
(b)

Figure 6: Coupling cell after brazing (a) Vacuum level during bake out, (b) bake out setup.

Figure 7: Side coupled brazed prototype.



(a)



(b)

Figure 8: (a) axial field profile by bead pull measurement (b) frequency spectrum by VNA.

CONCLUSION

The first side coupled prototype was simulated and constructed. Also, the vacuum and RF measurements were done for evaluation of its parameters. Measurement results represent that machining and brazing was done successfully and this procedure can be extended for construction of full dimension 6 MeV side coupled standing wave cavity for medical accelerators. The quality factor results of simulation and measurement are 14000 and 10000 respectively. But more attention should be given to machining and cleaning for better results of vacuum level and quality factor.

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