DESIGN AND SIMULATION OF HIGH POWER INPUT COUPLER FOR C-ADS LINAC 5-CELL ELLIPTICAL CAVITIES

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Abstract

Two 650 MHz elliptical cavity sections (elliptical 063, elliptical 082) are chosen to accelerate medium energy protons for China Accelerator Driven sub-critical System (C-ADS) linac. For each 5-cell cavity, RF power up to 150 kW in CW mode is required to be fed by a fundamental power coupler (FPC). A coaxial type coupler is designed to meet the power and RF coupling requirements. This paper presents the RF design, thermal analysis and multipacting simulations of the coupler for C-ADS 5-cell elliptical cavities.

INTRODUCTION

In the Chinese ADS project, the main linac makes use of 650 MHz β=0.63 and β=0.82 superconducting cavities to accelerate a beam current of 10 mA covering the energy range from about 180 MeV to 1.5 GeV [1]. The superconducting cavities are designed to work at gradient of 12 MV/m, and powered by a single FPC for each. In order to meet the requirements, a FPC with the capability to deliver 150 kW continuous wave RF power is designed. Table 1 shows several parameters of the 5-cell cavities and FPC.

Table 1: Main Requirements of the Cavity and FPC

Parameter	Value
Frequency	650 MHz
Beam current	10 mA
R/Q (elliptical 082)	514.6 Ω
Peak RF power	150 kW, CW
Coupling type	Antenna
Coaxial line Impedance	50 Ω

The basic design of the 650 MHz coupler is derived from the coupler of KEKB SC cavities, in consider of its simplicity in structure and reliability in operation with high RF power [2]. Some components and mechanical dimension are redesigned because of the difference in frequency and other considerations. However, the window must be assembled with the cavity in class-10 clean room to protect the cavity from contamination. The RF structure is carefully simulated by HFSS code. Then sufficient thermal, thermal-mechanical simulations are carried on with ANSYS code. In addition, we made multipacting simulations and the results is discussed.

RF STRUCTURE DESIGN

The design of 650 MHz FPC is based on a 50 Ω coaxial line, including a doorknob transition, a planar RF windowe and an antenna. Figure 1 shows the half structure of 3-D model for RF structure analysis.

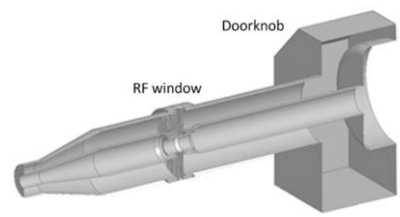

Figure 1: The half 3-D model of the 650 MHz coupler used in HFSS for RF structure design.

RF window is a critical component of the coupler. The window is made of 97.6% alumina ceramic, which works as a vacuum barrier for the cavity but let the RF power go through. The choke is an impedance-matching structure, meanwhile provides shielding for the window braze joints to reduce the electrical field. As shown in Figure 2, the electrical field near braze joints is obviously lower because of the choke structure and the window match the impedance well.

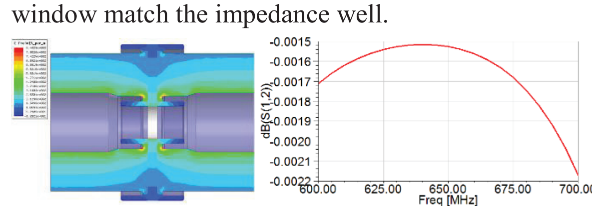

Figure 2: The E field of the window structure with 1 W RF power (left) and the S21 parameter of the RF window (right).

The transition between the coaxial line of the coupler to the WR1150 waveguide from the klystron is achieved by a doorknob configuration. The RF performance of the doorknob is sensitive to the mechanical dimensions. We have optimized dimensions of the doorknob (mainly the doorknob height, diameter and the distance from the shot circuit) aimed at a good impedance matching. Further simulations of the integrate coupler have been carried on. Figure 3 shows the calculated S11 curve of the whole

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coupler. The S11 is smaller than -50 dB at 650 MHz. The bandwidth is about 40 MHz at S11= -25 dB.

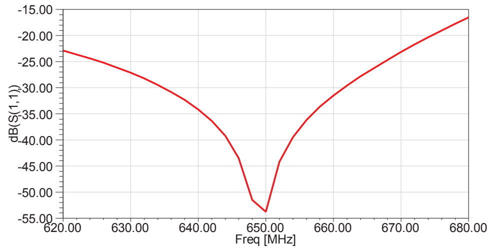

Figure 3: Calculated S11 parameter of the coupler

THERMAL DESIGN

Generally, there are two ways to cool down the out conductor, one is by anchors, and the other is by helium gas. For the 650 MHz coupler, which should deliver RF power up to 150kW, CW, simulations show that anchors are incapable to reduce the heat load to a reasonable level, as shown in Figure 4. We can see that the heat load to 2 K flange and 5 K anchor are mainly consist of the dynamic heat loss. Also it cannot be reduced by extending the out conductor.

Aiming to minimize the heat transferring to the cavity beam pipe, we select the helium gas to cool the cold part out conductor. A double-wall structure with a helium flow passage inside is designed.

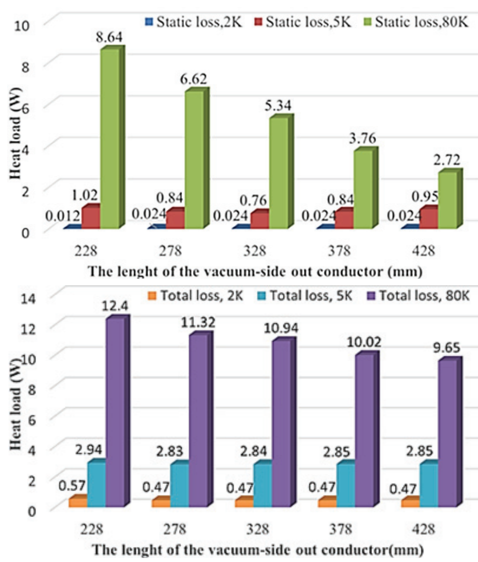

Figure 4: The static loss and total loss of 2 K flange, 5 K anchor and 80K anchor as the out conductor varies in different length with 150 kW power transmitted through.

The inner surface of the stainless steel out conductor is copper plated with a nominal thickness of 10 µm. The copper plating can reduce RF dissipation while minimally increasing the heat load to the 2 K flange at the same time.

The inner conductor of the coupler is a double-wall configuration so as to facilitate water cooling. The doorknob is cooling down by room temperature air with two force air cooling tube in its profiles. The average RF power loss in the ceramic and coaxial line of the window, was calculated to be around 100 W in total. These losses are handled by the cooling water in the inner conductor and the cooling air flow through the air gap in the out conductor.

Thermal and mechanical stress analysis were performed for the window under 300 kW RF power using the ANSYS code. As Figure 5 shows, the maximum temperature is 43℃, in the middle of ceramic window. The maximum stress from the heat load and the ambient pressure is about 28 MPa, nearly one tenth of the tensile strength of ceramic, as shown in Figure 6.

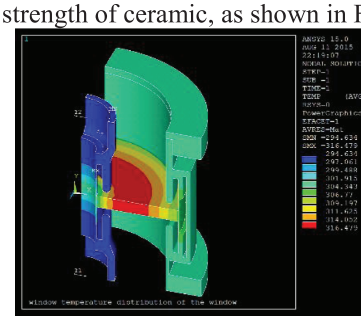

Figure 5: Temperature contour of the RF window at 300 kW, CW. Both the inner conductor cooling water temperature is and the window cooling air temperature is 20℃.

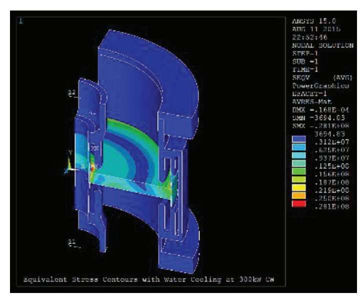

Figure 6: Stress contour of the window at 300 kW, CW.

MULTIPACTING SIMULATIONS

Multipacting is a serious problem for coupler operation [3]. It is important to know whether multipacting would happen at the operation power level or not. The simulations of multipacting in the vacuum side of coupler were performed with MultiPac 2.1, a 2D electron trajectory calculation code [4]. The analysis was carried on in the window structure and in the coaxial line with taper separately. Figure 7 shows the geometries used in the analysis.

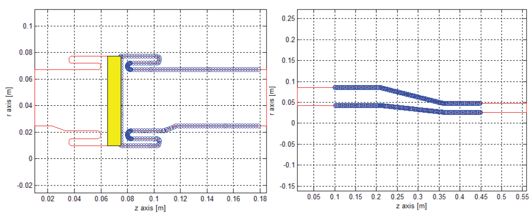

Figure 7: The window (left) and coaxial line (right) geometries for multipacting simulation. The blue dots are initial electrons.

The input power was swept from 1 kW to 150 kW and the emitted electron at deferent initial phase was calculated. As Figure 8 shows, after 20 times of impacts, nearly all of the free electrons were disappeared and the number of all electrons was less than initial electrons at all power levels below 150 kW which means there is no multipacting in the coaxial line for a standing wave. Simulations in the coaxial line with other reflection conditions come to the similar results. So is the results in the vacuum side of the window. Those simulations results indicate that there is no multipactor barrier under 150 kW for the 650 MHz coupler.

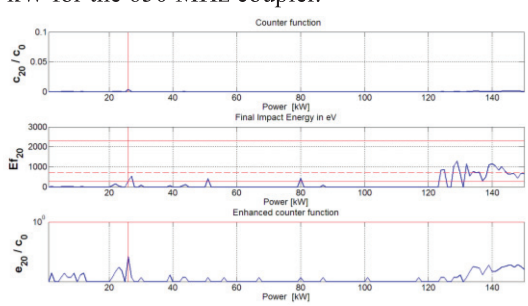

Figure 8: From the top to the bottom, the electron counter, the average impact energy of the last impact in eV and the enhanced electron counter in the coax line with a taper for a standing wave.

SUMMARY

This paper reports the RF structure design, thermal design and multipacting simulations of the C-ADS 650 MHz coupler. The results of the simulations would offer great assistance in the manufacture and in the later RF conditionings of the prototype coupler in the near future.

REFERENCES

[1] LIU Zhen-Chao, et al., "An ADS 650 MHz medium beta cavity study and design", Chinese Physics C.

[2] S. Mitsunobu, et al. "High power input coupler for KEKEB SC cavity", Proceedings of the 1999 Workshop on RF Superconductivity, Santa Fe, NM, USA, 1999.

[3] Mark S. Champion, "RF Input Couplers And Windows: Performances, Limitations, And Recent Developments", Proceedings of the 1995 Workshop on RF Superconductivity, Gif-sur-Yvette, France, 1995, pp. 195-221.

[4] Pasi YLä-Oijala, et al., *MultiPac 2.1*, 2001.

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