A STUDY OF SELF-CONSISTENT ELECTROMAGNETIC AND COOLING CONFIGURATION OF AN OFHC COPPER REBUNCHER FOR SARAF.

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ABSTRACT

A four gap OFHC copper rebuncher is developed at SNRC as a research study and a risk reduction for the MEBT of SARAF Phase II proton/ deuteron linac. The rebuncher is designed to bunch a 5 mA CW beam at 176 MHz. Considering utilizing this cavity for enhancing the beam energy, the cooling configuration is explored for a cavity voltage of 300 kV, consuming 20 kW dissipated power, at a peak electric field of 16 MV/m, equivalent to the Kilpatrick limit.

Keywords: Fluent, rebuncher, heat convection, RF dissipated power,

INTRODUCTION

An Oxygen Free High Conductivity (OFHC) copper 4 gap rebuncher is developed for the proton/ deuteron 5 mA Continues Wave (CW) SARAF linac at 176 MHz. The rebuncher beam energy is 1.3 MeV/u (Beam beta=5.3%) [1]. We consider applying this cavity for enhancing the beam energy in order to reduce the upstream RFQ load. The required cavity voltage according to beam dynamics simulation is 150 kV with an aperture diameter of 40 mm at a beam energy of 1.3 MeV/u with a un-coupled Q value of 8000 [2]. In this case the peak electric field is 16 MV/m (the Kilpatrick Criterion in our frequency) and the expected dissipated power is 20 kW. For normal functioning as a rebuncher the maximum field is 50% and the dissipated power is 25%. The rebuncher cooling configuration for 20 kW dissipated power is explored in this study.

MODEL ANALYSIS

The rebuncher configuration is shown in Fig. 1. The main components are: the RF cavity chamber, the upper fork with two drift tubes and the base cone with a drift tube. All these elements are made from OFHC copper. The electro-magnetic properties were simulated with CST microwave studio using the eigen-mode solver (Fig.2). Obtained surface current distribution was scaled to operational parameters and used in preliminary design of the cooling system.

The next stage of the research was to simulate the 20kW injected power regime at ANSYS HFSS. The driven model HFSS solver (Fig.3) reproduced the similar results pattern that was generated by the CST Eigen mode solver. Results of HFSS driven mode solver are shown in Fig.4: the resonance frequency is 176.05MHz with FWHM 48 kHz (coupled Q-factor is 3700).

The temperature mapping and the heating power flow were received by the rebuncher ANSYS Fluent solver and the HFSS driven solver co-simulations. Several evolved cooling configurations were studied including cooling of the drift tubes (Fig. 5). For the derived configuration, the temperature profile on the cavity surface rises up to 38°K (Fig. 6).

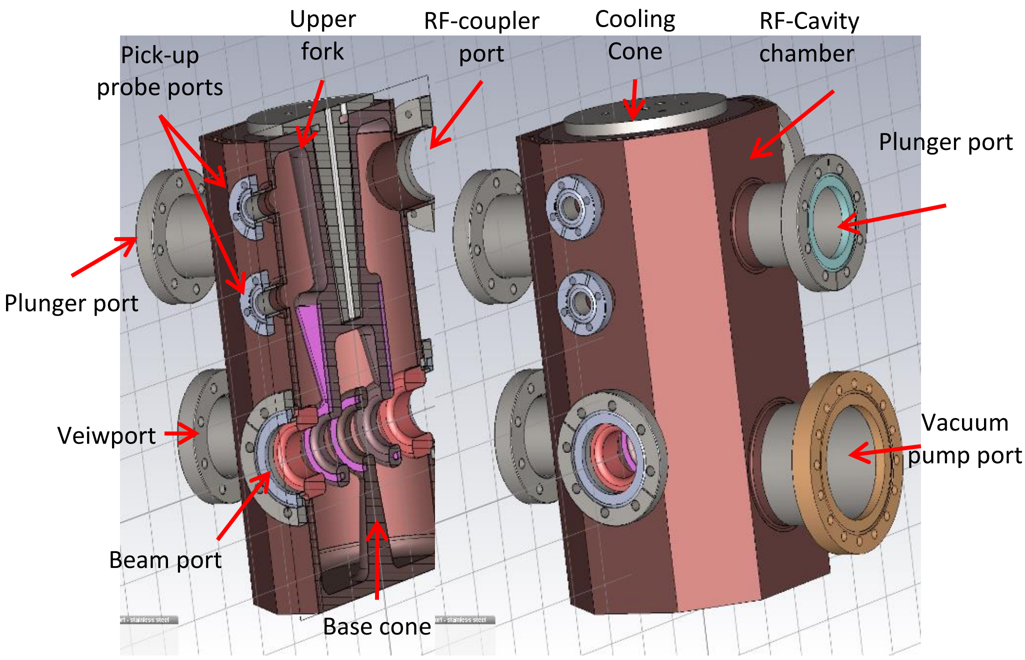

Figure 1. The rebuncher design

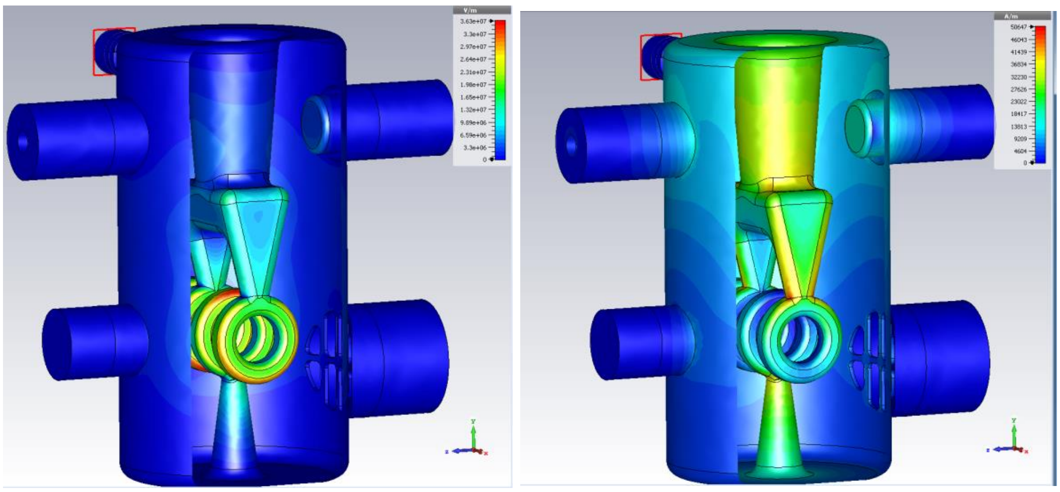

Figure 2. The induced Eigen mode surface electric field (left) and magnetic field (right) at 176 MHz normalized for a 1 Joule rebuncher stored energy received from CST MW studio

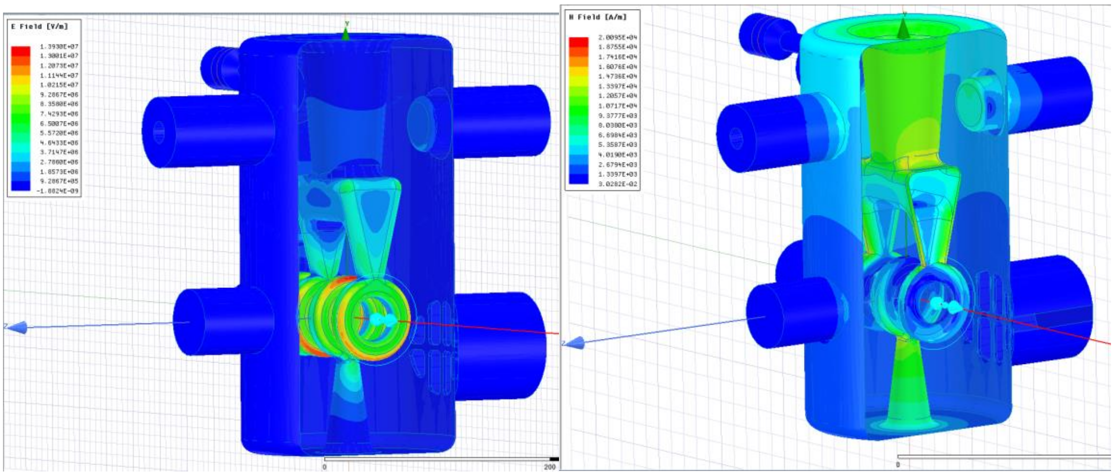

Figure 3. The induced surface electric field (left) and magnetic field (right) for 20 kW input power received with driven mode HFSS solver.

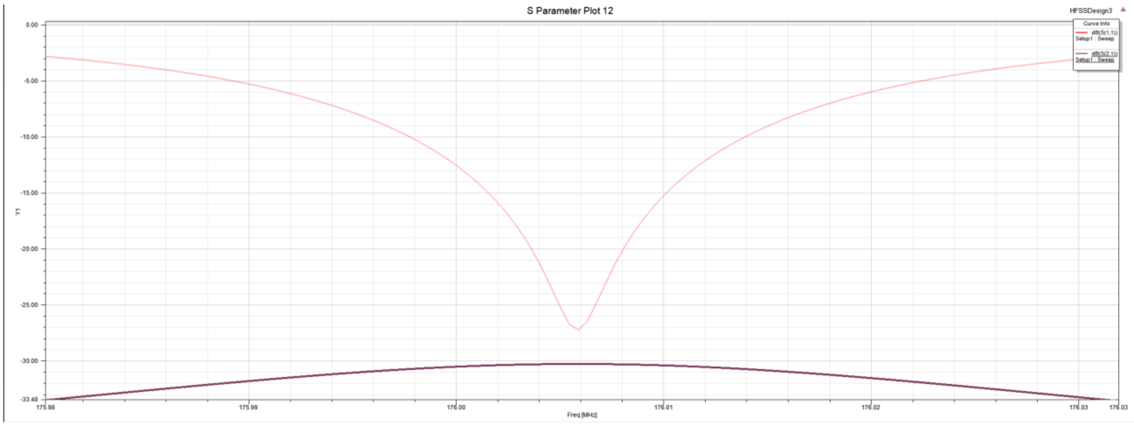

Figure 4. HFSS S-parameters. S11 (reflected, top line) and S21 (pick-up, bottom line) curves. Coupled Q-factor 3700.

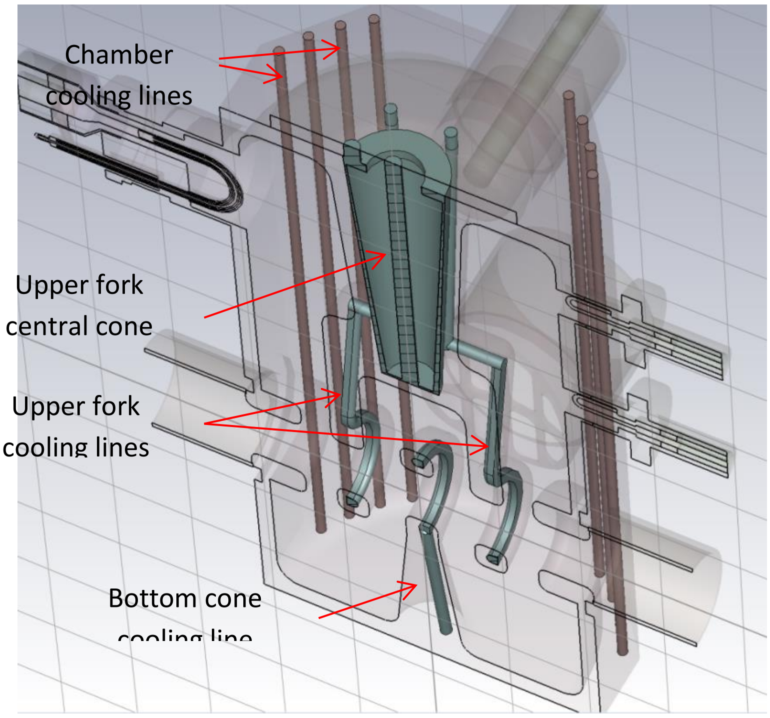

Figure 5. The derived cooling configuration

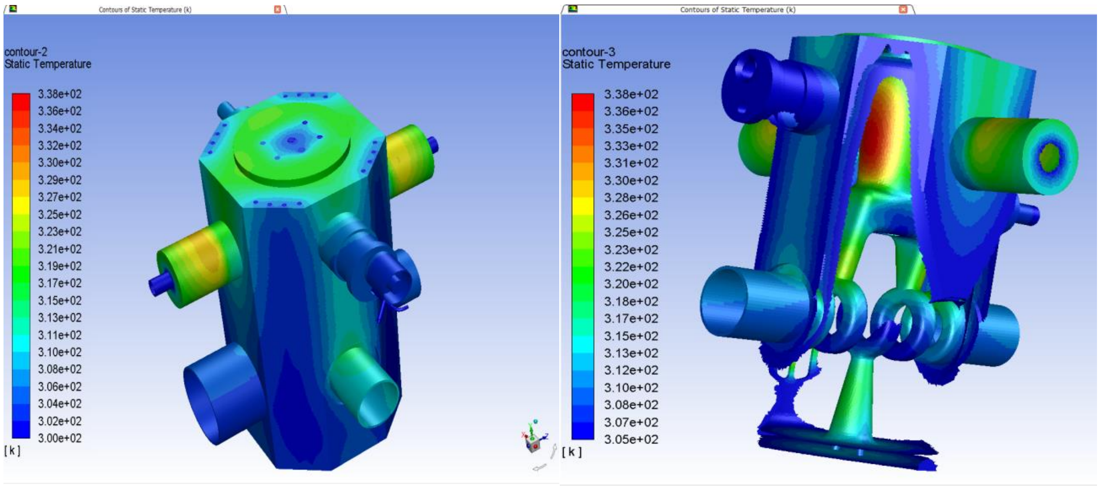

Figure 6. The rebuncher temperature ANSYS Fluent map for 20 kW dissipated power assuming reasonable distilled cooling water velocity of 5 m/s demonstrate modest temperature rise of 38K°

VERIFICATION ANALYSIS

The inlet fluent velocity was studied in the range of 3-7 m/s for the 20kW dissipated power. The temperature profile was examined for the inlet flow velocity of 5m/s and for cell mesh length of 3 and 4 mm. Comparison of the results for different mesh size does not show any significant deviation (less than 1°K). Due to this fact, all future simulations were run with 4mm cell mesh-length. A 3D velocity distribution in a cooling channel corner is shown in Fig.7. It was found that the temperature rise reduces from 38°K to 33°K for coolant inlet flow velocity variates in between 5-7 m/s. At the same time, the simulated pressure drop along the cooling lines increases above 1Barr. Based on these simulations, the recommended distilled water flow inlet velocity is 5 m/s.

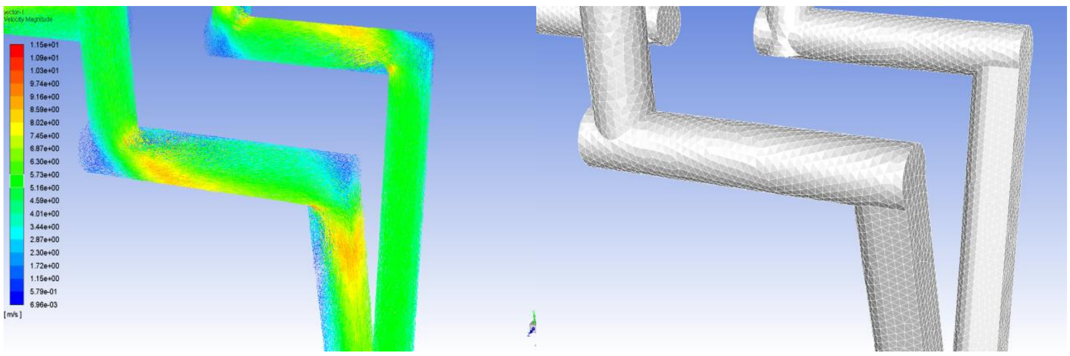

Figure 7. The fluent velocity path (left) for the derived 4mm cell mesh-length (right)

CONCLUSIONS

An effective cooling configuration was derived in this study for the 4 gap rebuncher. The surface temperature increment of 38°K for 20 kW dissipated power for a reasonable distilled water cooling inlet flow of 5 m/s were achieved. The total water pressure drop in the cooling system is less than 1 Barr. The next step is to manufacture the rebuncher and to condition it for 5-20 kW dissipated power.

REFERENCES

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[2] B.Kaizer, J.Rodnizki, E.Farber, A.Perry, L.Danon et al, "Study and Development of CW Room Temperature Rebuncher for SARAF Accelerator", NIMA, 871, pp.161-168, 2017