A.16: Physics design of a 5 cell β_g= 0.61, 650 MHz superconducting radio frequency cavity

Physics design study of a 5-cell β_g= 0.61,650 MHz super conducting radio frequency cavity, has recently been completed in Accelerator and Beam Physics Laboratory of Materials and Advanced Accelerator Sciences Division, RRCAT. A set of such cavities, along with the focusing elements will be used for accelerating H^- particles in the medium energy range (150 - 500 MeV) of 1 GeV injector linac for the proposed Indian Spallation Neutron Source.

Geometrical parameters of the mid cell were optimized for maximum achievable acceleration gradient (E_a), using a step by step, one-dimensional optimization technique. This was followed by the optimization of end cells, in order to achieve the required field flatness, as well as to avoid trapping of higher order modes. Calculations of the threshold beam current for onset of regenerative beam break up (BBU) instability were also performed, followed by calculations of wake field and its effect on beam dynamics. Finally, studies were performed on the static as well as dynamic Lorentz Force Detuning (LFD), based on which the stiffness design of the cavity was optimized.

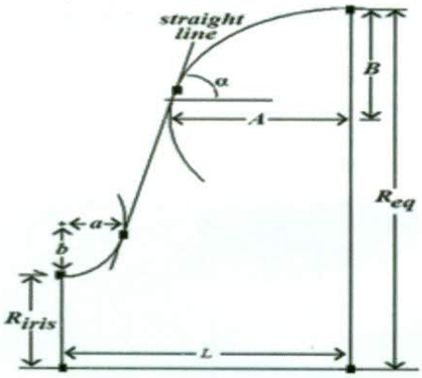

Fig. A.16.1: Schematic of the half-cell

Fig. A.16.1 shows the cross section of the half-cell, which is obtained by joining two elliptical arcs by a common tangent. The three-dimensional cavity shape is a figure of revolution of this cross section around the beam axis, and is described by seven parameters - iris ellipse radii a and b, equator ellipse radii A and B, iris radius R_{iris}, equator radius R_{eq}, and half-cell Length L. Since the cavity operates in π mode, $L = \beta_g\lambda/4$, where λ is the free space wavelength corresponding to the operating RF frequency. Choice of R_{iris} is made to ensure that it is just enough to provide the required cell-to-cell coupling, while not affecting the shunt impedance significantly. The maximum feasible value is chosen for the cavity wall angle α since it results in reduced heat loss on cavity wall. In our design, this value is 88°. The required resonant frequency is achieved by tuning R_{eq}. The remaining three independent geometrical parameters are optimized to minimize the value of E_{pk}/E_a and B_{pk}/E_a, where E_{pk} and B_{pk} are the peak electric and magnetic fields respectively on the cavity surface. The optimized values of geometrical parameters of the mid-cells of the cavity are shown in Table A.16.1. Radius of the beam pipe is same as R_{iris}. For our design, the target value of $E_{pk}/E_a \leq 2.36$ and $B_{pk}/E_a \leq 4.56$ mT(MV/m) ensures an accelerating gradient ~ 15.4 MV/m.

Table A.16.1: Optimized parameters of β_g=0.61 cavity

Geometry parameters	Mid-cell	End-cell (entry)	End-cell (exit)
R_{iris} (mm)	44.00	44.00	44.00
R_{eq}(mm)	195.591	195.591	195.591
L (mm)	70.336	71.55	71.24
A (mm)	52.64	52.64	52.25
B (mm)	55.55	55.55	55.55
a (mm)	15.28	15.28	15.28
b (mm)	28.83	28.83	28.83

End-cell parameters are same as the mid-cell parameters, except that there is slight tuning in the values of L and A. For β_g = 0.61 cavity, there was a trapped monopole mode at 1653.20 MHz. Hence, in order to take care of the trapped mode, in addition to L, we needed to tune A for the end cell at the exit end. HOM studies have been performed using the computer codes SLANS. In the absence of HOM couplers, the CW average of threshold current for BBU was calculated as 0.7 mA, which is acceptable. Calculations of heat load shows that the cryogenic load due to HOMs will not be very significant if we keep the external quality factor Q_{ext} for HOMs less than 10^8.

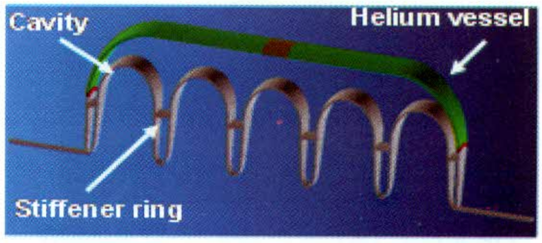

Fig. A.16.2: ANSYS model of cavity with He vessel

ANSYS model of the cavity with helium vessel, used for LFD studies is shown in Fig.A.16.2. Based on these studies, the cavity wall thickness and helium vessel thickness are chosen as 4 mm and 5 mm respectively, and the radial location of the stiffener ring is chosen as 124 mm. Diameter of the helium vessel is chosen as 504 mm, with end closure in "tori-spherical" shape having torus radius of 120 mm. Further details of this work can be found in IEEE Trans. Appl. Supercond., 24 (2014) 3500216.

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