A.12: Electromagnetic Design of $\beta_G = 0.9$, 650 MHz Superconducting Radio Frequency Cavity

The electromagnetic design study of a multi cell, $\beta_G = 0.9$, 650 MHz elliptic superconducting radiofrequency cavity, which can be used for accelerating H^- particles in the high energy section of the 1 GeV linear accelerator for the proposed Indian Spallation Neutron Source has recently been completed in Accelerator and Beam Physics Laboratory of Materials and Advanced Accelerator Sciences Division, RRCAT. We have followed a typical TESLA type cavity shape, based on two elliptic arcs joined by a straight line, as shown in Fig. A.12.1. The three-dimensional cavity shape is a figure of revolution around the beam axis, obtained using the contour shown, and is described by the following seven independent 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. The wall angle shown in the figure is a parameter that can be derived from these seven parameters. For the π mode operation, one chooses $L = \beta_g\lambda/4$ for synchronization. The iris radius is fixed by beam dynamics considerations and aperture requirements. Optimization of the cavity geometry involves finding the value of the remaining five parameters such that the accelerating gradient is maximized for a given value of maximum allowed surface field, and the power loss on the cavity is minimized for a given energy gain. The typical approach followed in the literature for this purpose, is the multi-dimensional optimization, which is tedious. We have developed a step by step, one-dimensional optimization technique to ultimately perform a multi-variable optimization. Using this approach, it is possible to do the cavity design starting from scratch.

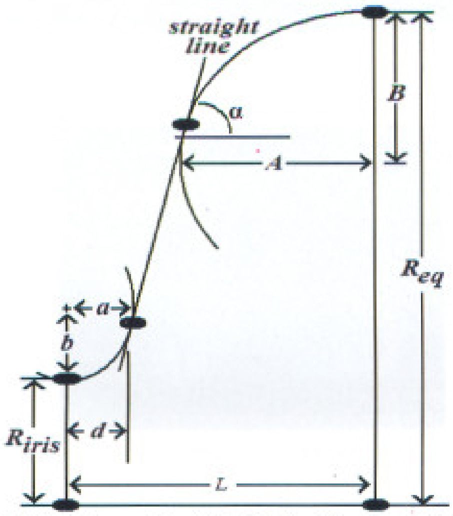

Fig. A.12.1: Schematic of the half-cell of an elliptic cavity.

The number of cells in the cavity is chosen to be 5 and is optimized on the basis of transit time factor, field flatness and other considerations. Parameters of the mid cell, as found using our optimization technique are given in Table A.12.1. The design of the end cell of the cavity is optimized such that the resonant frequency of the multi cell cavity matches with that of the mid cells, to ensure maximum field flatness in the cavity. For this, we have optimized the length L_e of the half-cell adjacent to the beam pipe. The optimized value of L_e is obtained as 105.8 mm and the wall angle α is accordingly changed to 82.75° for the end cell. The remaining parameters are shown in Table A.10.1.

Table A.12.1: Optimized geometry for the mid cell.

Parameter	Magnitude	Unit
R_{iris}	50.00	mm.
R_{eq}	199.92	mm.
L	103.77	mm.
A	83.27	mm.
B	84.00	mm.
a	16.79	mm.
b	29.45	mm.
α	85°	

In the optimized design, assuming an allowed limit of peak surface electric and magnetic field as 40 MV/m and 72 mT respectively, the maximum acceleration gradient possible is 19.2 MV/m. The ratio of shunt impedance to quality factor (R/Q) for the operating mode is calculated to be 608.7 Ω. For the 5-cell cavity, five normal modes have been obtained and the dispersion curve has been plotted, using which the inter-cell coupling coefficient k_c is estimated to be 0.75%. The field flatness is calculated to be 0.992, which is very close to 1.0 as desired.

Higher order monopole as well as dipole modes supported by the cavity have been studied using the electromagnetic code SLANS and the threshold current for regenerative beam break up instability excited by dipole modes has been estimated. The energy spread induced in the beam due to longitudinal wakefield and the parasitic heat loss due to excitation of higher order modes have also been estimated.

We have performed the Lorentz Force Detuning (LFD) studies and shown that keeping the thickness of cavity wall as 4 mm and choosing appropriate position of the stiffener ring and appropriate value of the stiffness of the helium vessel, it is possible to tune the cavity to compensate for the LFD.

The full details of this work are available in RRCAT Internal Report No 2012-4.

Reported by:
A. R. Jana (arjana@rrcat.gov.in) and V. Kumar