Comparative Design Study And Analysis of 650 MHz, Beta=0.61 SCRF Cavity

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Abstract. In Accelerator Driven Subcritical System (ADSS), when high energy (~1 GeV), high current (~ 20 mA or more) proton beam hits the target of heavy element (such as Th, Pu or U etc.), spallation neutrons are produced. Spallation neutrons are used for sustaining fission chain reaction in ADSS. So, a high energy, high current proton accelerator is required to build for ADSS. For high intensity proton beam, linear accelerator (Linac) with superconducting rf linac cavity is one of the best choices. Design, Analysis and Development of high-β multi-cell elliptical shape Superconducting RF linac cavity has been taken up by VECC, Kolkata. The project aims to provide state-of-the-art technology achieving very high electric field gradient in superconducting linac cavity, which can be used in high energy high current proton linear accelerator. Influence of geometric parameters on different RF design parameters has been analyzed for 650 MHz, β=0.61, 5-cell elliptical cavity and the cavity shape optimization have been done using 2D SUPERFISH and 3D CST MICROWAVE STUDIO codes. This paper discussed the comparative study of RF design parameters for two types of elliptical cell shapes, like re-entrant and non re-entrant, that has been carried out for single cell 650 MHz, β=0.61 SCRF cavity.

Keywords: SCRF Cavity, elliptical shape.re-entrant, non-reentrant
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INTRODUCTION

The elliptical shaped cell of the cavity consists of two elliptic arcs and, possibly, a straight line between them and thus the shape of an elliptical cavity is determined by geometric parameters[1] like cell length(L), equator radius(D/2), iris radius or aperture radius (Riris), iris ellipse ratio(a/b), equator ellipse ratio(A/B), slope of the side wall (α)and the distance measured from the iris plane.

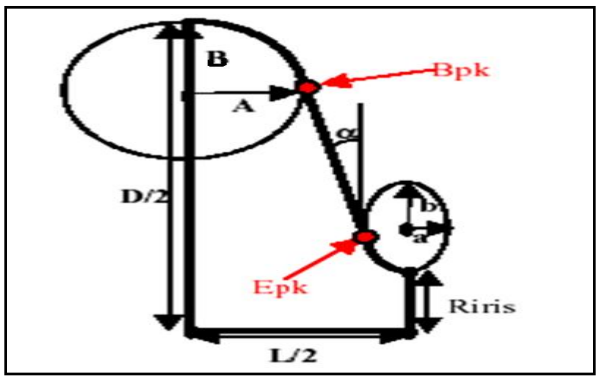

FIGURE 1. Geometry of Non-reentrant elliptical shape

The main figures of merit for an elliptical-cell design of a Superconducting RF cavity are Epk/Eacc, Bpk /Eacc,G and R/Q.

Where, Epk=peak surface electric field

Bpk=peak surface magnetic field,Eacc= accelerating gradient,

G=geometric factor,R/Q=shunt impedance/Quality factor

Iris radius very strongly influences the above mentioned merit values[2] .With the decrease of Riris, Epk/Eacc, and Bpk/Eacc decrease ,G and R/Q increase.[3]By choosing proper value of geometric parameters, optimal merit values have been determined for 650 MHz, β=0.61, 5-cell elliptical cavity. A comparison of re-entrant and non-reentrant shape elliptical cavities has been done in terms of Epk/Eacc, Bpk /Eacc,G and R/Q for same aperture radius at 650 MHz.

RE-ENTRANT SHAPE CAVITY

The peak surface electric (Epk) and magnetic field(Bpk) decide the achievable accelerating gradient(Eacc) in elliptical shape cavity. Both Epk and Bpk increase proportionally as Eacc is raised. The ratios of Epk/Eacc and Bpk/Eacc are determined solely by the cavity geometry.Traditionally the cavity shape is optimized, to reduce Epk/Eacc as field emission increases with Epk/Eacc and limits Eacc. By proper surface treatment, field emission in a elliptical cavity can be reduced.But along with the field emission problem ,there is a fundamental limit in Eacc due to an intrinsic limit referred to as the RF critical magnetic field(Bcrit) on surface of superconductorF .[4] When the Bpk(or Hpk) is raised to this critical value, superconductivity breaks down. To overcome this fundamental limit, the ratio Bpk/Eacc has to be reduced by changing the cavity shape and this leads to the re-entrant elliptical shape cavity.Re-entrant cavities are cavities with negative value of (α) [4]

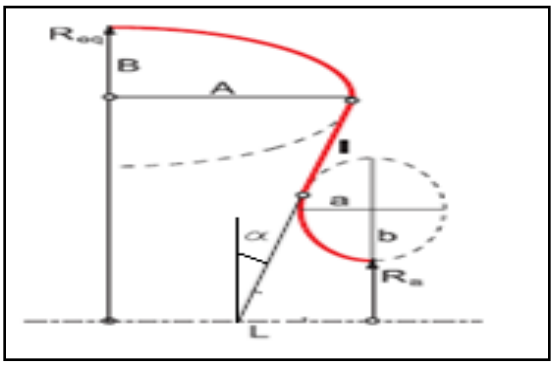

FIGURE 2. Geometry of Re-entrant elliptical shape

Along with the lower Bpk/Eacc value, other advantages of this shape are higher value of G and R/Q. This Implies that lower losses on the cavity surface and lower cryogenic need. But in case of re-entrant type of cavity ,Epk/Eacc ratio is somewhat higher .[4]

DESIGN RESULT FOR 650MHZ, β=0.61, 5-CELL CAVITY

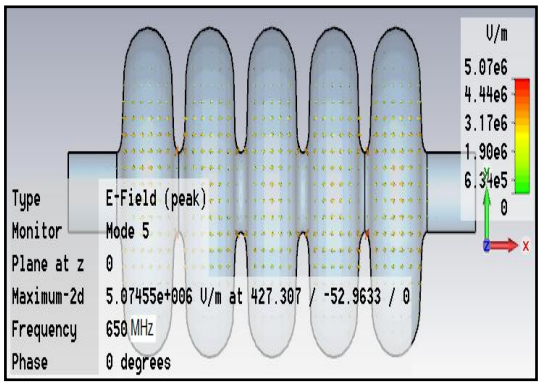

FIGURE 3. E-field lines for accelerating mode (CST microwave studio)[3]

TABLE 1. Figure of merits

Figure of merits	Value
E_{pk}/E_{acc}	3
B_{pk}/E_{acc}	4.84
R/Q	296
G	200

COMPARISON OF CELL SHAPES

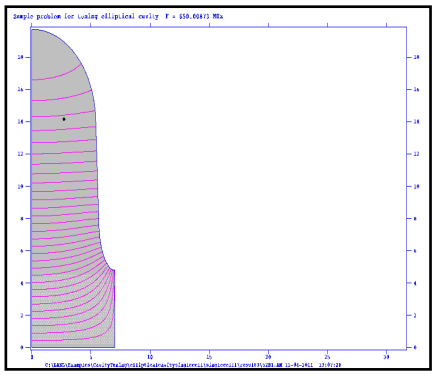

FIGURE 4. E-field lines for accelerating mode (non-reentrant shape, Superfish simulation)

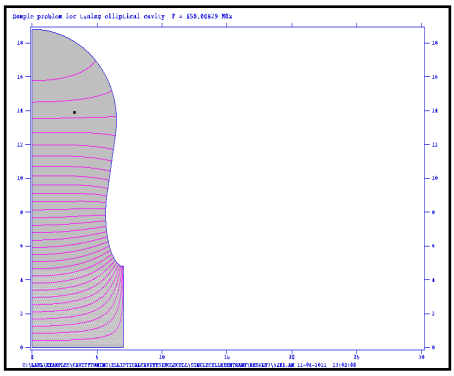

FIGURE 5. E-field lines for accelerating mode (reentrant shape, Superfish simulation)

Following table shows the figure of merits for 650MHz, β=0.61 single cell non-rentrant and re-entrant cavity both having the aperture radius of 48 mm.

TABLE 2. Comparison of figure of merits

singlecell	Epk/Eacc	Bpk/Eacc mT/(MV/m)	R/Q	G
Non-reentrant	3.048	4.7172	58.6	192.9
Re-entrant	3.085	4.525	63.2	202.526

CONCLUSION

Epk/Eacc, Bpk /Ecc,G and R/Q. are good basis of comparison of RF design of elliptical shape superconducting cavities. All the above parameters of the re-entrant shape appear to be better than non-reentrant type except Epk/Eacc. Effect of higher Epk/Eacc can be taken care of by proper surface treatment of the cavity.

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