Development of Superconducting RF Cavity at 1050 MHz Frequency for An Electron LINAC

S. G. Sarkar, J. Mondal and K. C. Mittal

Acclerator & Pulse Power Division, Bhabha Atomic Research Centre, Mumbai 400085, India

Abstract. This paper reports the design of a prototype superconducting cavity at 1050 MHz and design of associated die punch and machining fixtures for the cavity fabrication. The cavity is of β= 1 and elliptical in shape. The circle-straight line-ellipse-type structure design has been optimized by "SUPERFISH" – a 2 dimensional code for cavity tuning. The 3 Dimensional EM field analysis of the cavity structure has been done using "CST" software. The ratio of the maximum surface electric field to the accelerating gradient, Epk/Eacc, is optimized to 1.984 and Hpk/Eacc is optimized to 4.141 mT /(MV/m) . Bore radius of the cavity has been chosen such a way so that the cell-to-cell coupling remains as high as 1.85%. The cavity is designed to achieve 25 MV/m accelerating gradient.

Keywords: Accelerator; LINAC, Superconductivity.
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INTRODUCTION

A prototype β=1 superconducting elliptical cavity at 1050 MHz is designed for a proposed electron LINAC. The accelerating gradient of the cavity is taken to be 25 MV/m. In order to design a superconducting cavity it is necessary to maximize R/Q of the fundamental mode and minimize Epk/Eacc and Bpk/Eacc. This is necessary because high surface magnetic field can quench the cavity and high surface electric field can start field emission. It is also important to calculate higher order modes in any new designed structure. The design study of the cavity is given in details below.

CAVITY SHAPE OPTIMISATION

An elliptical cavity design is a compromise of various geometrical parameters. Cavity shape optimization has been done by means of finite difference based 2D simulation code SUPERFISH. The optimised design parameters of the fundamental modes were reconfirmed by 3D simulation code CST, microwave studio. Higher order modes (HOM) of the cavity are also calculated using CST. The circle-straight line-ellipse-type (TESLA type) structure is chosen and the influence of different shape variables on Epk/Eacc and Bpk/Eacc are studied. Shape variables of the cavity include dome vertical semi-axis (R_c), the dome-ellipse aspect ratio, the iris-ellipse aspect ratio a_I / b_I, and the wall angle α (as shown in the figure 1). the cavity diameter D is tuned to get the designed frequency. The cavity cell length L= βλ/2 is already fixed for a given frequency.

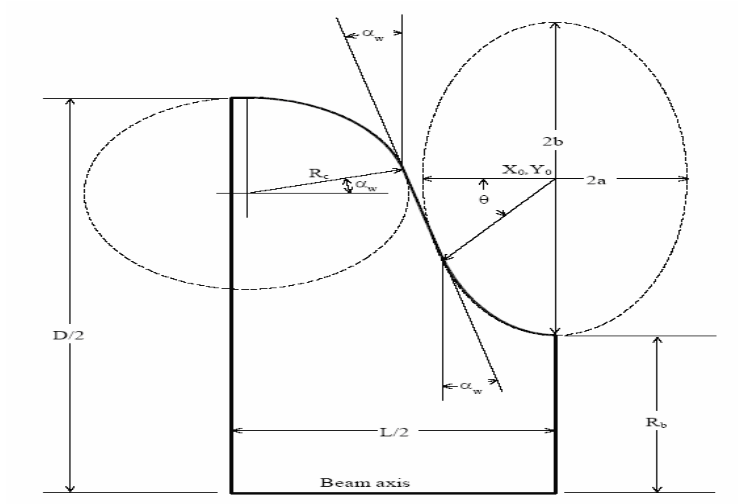

FIGURE 1. Symmetric half cavity shape and parameters

Bore radius is an important parameter for optimization and it is usually decided in conjunction with beam dynamics study and cell to cell coupling coefficient for multi-cell cavity. Larger bore radius may decrease beam loss but peak field and power loss increases with beam radius. Bore radius has been chosen to be 43 mm to keep the cell to cell coupling coefficient as high as 1.85%.

TABLE 1. Cell to cell coupling coefficient for different bore radius

Bore Radius (mm)	Cell to cell Coupling Coefficient (%)
39	1.2
41	1.44
43	1.85

The wall angle influences the mechanical behavior of the cavity. From the figure 2 it is observed that Epk/Eacc decreases with decrease in wall angle but Bpk/Eacc shows a deep at wall angle 12.5 degree. Hence the wall angle is chosen to be 12.5 degree. Similarly iris ellipse ratio finds a local minimum at a particular value. The optimized design parameters of the cavity are listed in the Table 2.

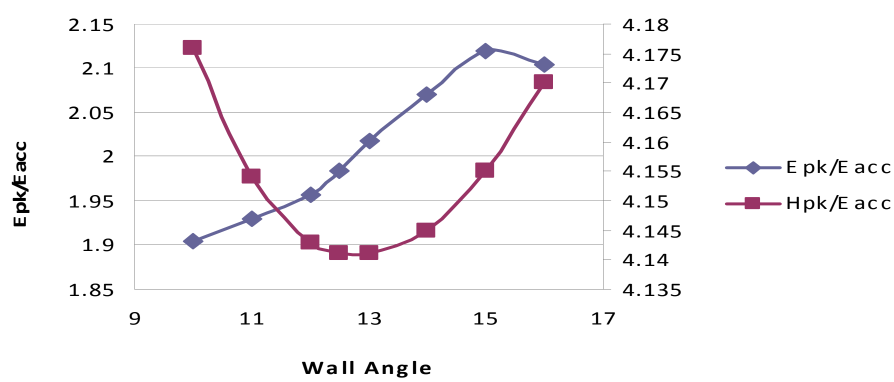

FIGURE 2. Optimization of wall angle

TABLE 2. **Design parameter of β=1 1050 MHz cavity**

Parameter	Value
Dome radius	52.38 mm
Wall angle	12.5 Degree
Cavity Diameter	255.4 mm
Cavity length	71.379 mm
Bore radius	43 mm
Ellipse iris a	14.83 mm
Ellipse iris b	23.18 mm
Accelerating Gradient	25 MV/m

3 Dimensional Electro-magnetic Field Analysis

Electromagnetic property of optimized cavity shape carried out in SUPERFISH is compared with 3 Dimensional code CST microwave studio. The comparison of the results is tabulated in Table 3. Figure 3, shows electric and magnetic field distribution inside the cavity as calculated by CST. It is critical to calculate HOM since they can leads to beam break up. HOM and their corresponding R/Q are calculated using CST eigen-mode solver. The R/Q spectrum of the HOM is shown in Figure 4 below.

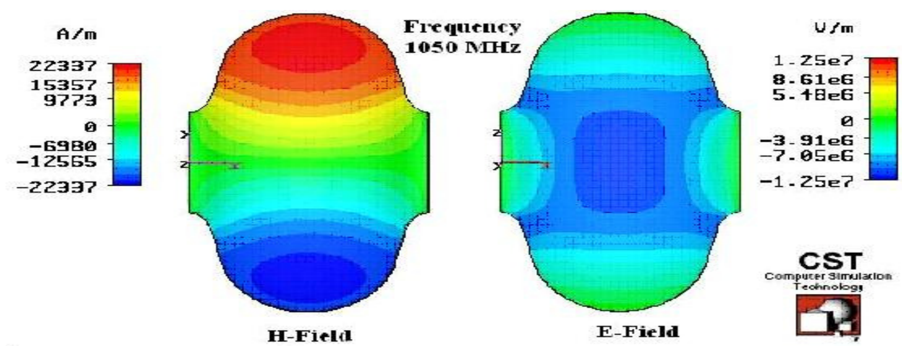

FIGURE 3. EM field values as obtained from CST

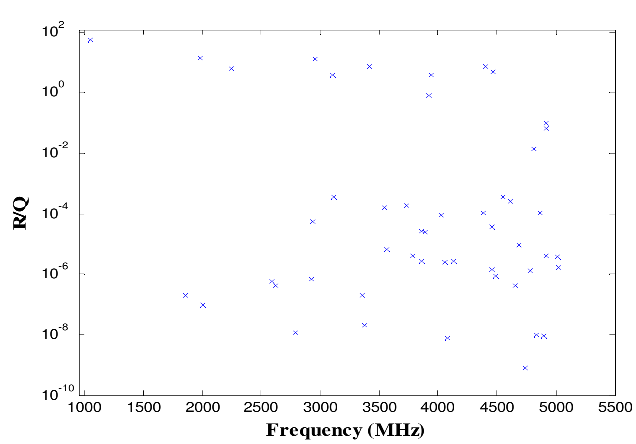

FIGURE 4. Calculated R/Q spectrum

TABLE 3. Comparison of CST and SUPERFISH result

	Value SUPERFISH	Value CST
Epk/Eacc	1.984	2.21
Bpk/Eacc	4.14 mT/(MV/m)	4.8 mT/(MV/m)
Cell to cell coupling coefficient	1.85%	1.84%
Fundamental R/Q	57.22 Ω	57.089 Ω

Die and Machining Fixture Design

Once the cavity design is fixed, next step is to design die and machining fixture. Outer surface of the male die has exactly the same profile as cavity inner surface. A coining ring will also be used for shaping iris region. Cavity will be formed by die punching. Hence for the die fabrication, Aluminum 7075 has been chosen for its superior mechanical quality. A step of 2 mm has also been provided at the equator and iris region of the cavity for the ease of Electron beam welding. Figure 5 shows typical die and machining fixture and their assembly.

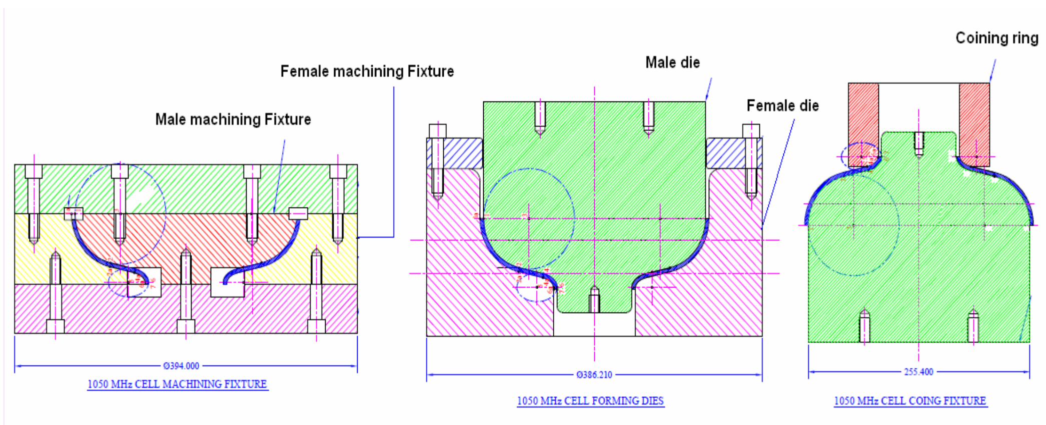

FIGURE 5. Die and Machining fixture assembly

CONCLUSION

In this paper we have discussed the cavity shape optimization of a prototype single cell superconducting cavity of 1050 MHz frequency and β=1. The higher order modes of the newly designed cavity are also calculated. Die and machining fixtures for the cavity has been designed. Fabrication of the cavity is now in progress.

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