THE ELECTROMAGNETIC DESIGN ON SPOKE CAVITY

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Abstract

The frequency of the spoke cavity is 350MHz, and the geometric β is 0.175. By using 3D code, the shape of spoke cavity is optimised. The optimisation target is the lower peak surface field at constant E_0. Finally, the E_{pk}/E_{acc} and B_{pk}/E_{acc} reach 3.18, and 7.35mT/MV/m, respectively, by changing the size of the spoke cavity.

INTRODUCTION

Because of power saving, there is a trend to replace the normal cavity by the superconductivity cavity (SC) in building new accelerator. Now, the SC spoke cavity becomes the one possible chosen structure to accelerate low β proton. This advanced accelerating structure may be used for ADS. So we begin to study some key structures such as RFQ, DTL, the spoke cavity, *etc.*.

In this paper, we will briefly introduce our design work on a 350MHz spoke cavity with geometric β = 0.175. In the second section, the geometric design and computer model is described. Then in the following section the optimisation of the cavity is conducted by varying several important geometric parameters, aimed for the minimum ratio of the surface peak E&B fields to the accelerating field.

SPOKE CAVITY DESIGN

For a SC structure, the cavity shape design is aimed to find lower electric and magnetic surface peak fields at a fixed accelerating field. In the design procedure, the accelerating length (L_{ac}) is fixed as $2/3\beta_g\lambda$, where β_g is the geometric β. When other parameter of the cavity changed, the cavity is tuned through changing the radius of the cavity.

According to the reference [1], three different spoke types are compared. The results appear that the racetrack type is better. So the racetrack spoke type is chosen as our spoke.

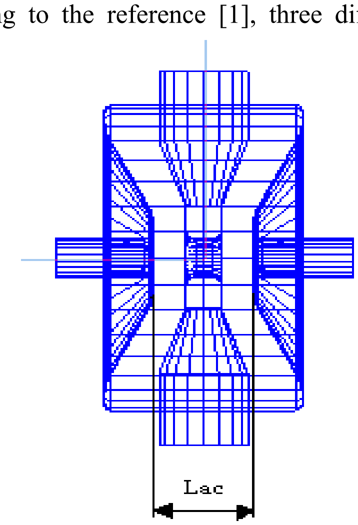

Figure 1: Section of spoke cavity.

The cavity consists of four parts: cavity wall, spoke, beam tube and two end walls. The cavity has one independent parameter: radius. The spoke consists of three parts: racetrack, spoke base and middle connector. Racetrack has 3 parameters: width, thickness, and height. Spoke base has two parameters: radius and it's location. For end wall, it has three parameters: top plate radius, height, and bottom plate radius. In this paper, the height of end wall is fixed because of the length of the cavity is twice as large as L_{ac}. The beam tube has two parameters: radius and length. As for the real situation, there is a chamfer at the intersection between the two parts. It is beneficial for the mechanical structure and distribution of the E and B field.

Table 1: The parameters of cavity model (cm)

Cavity radius	21.287
Racetrack width	11.44
Racetrack height	12
Racetrack thickness	2.946
Spoke base radius	4.778
Spoke base location	15
End wall top plate radius	3.85
End wall bottom radius	16.5
End wall thickness	4.995
Beam tube radius	2.5
Beam tube length	5

The spoke cavity, in fact, has the RF pickup tube, power input coupler tube and cleaning tube. If the simulation model includes these parts, it will destroy the structure symmetry, and hence, spend longer time to get a result in the computer simulations. All those parts are far from the maximum electric and magnetic fields, so at beginning, we can obtain a good approximation with the simulation model without these parts. Consequently, only one eighth of the cavity is modelled, saving a lot of computing time and memory.

In the post processing, the maximum surface field searched automatically by the code is always not the real value due to the coarse mesh. From the result, we can know that maximum magnetic field is at the spoke base and the maximum electric field is at the centre of the end wall or the racetrack crook, which faces the end wall. Three lines could be made from intersecting the model with the three planes: x-y plane, y-z plane and x-z plane. Then using the code, the maximum surface field is automatically searched on these three lines. E_0 and T (transit time factor) are scaled with the accelerating length (L_{ac}), instead of the overall physical cavity length.

SIMULATION RESULTS

At first, the minimum ratio of the maximum electric surface field to accelerating field is searched. The ratio dependence on the end-wall top-plate radius is depicted in Fig. 2. When the end-wall top-plate radius decreases, the

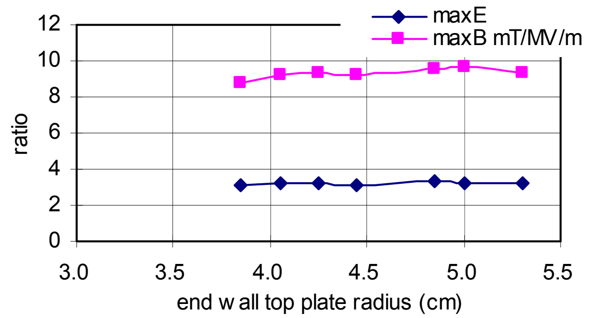

Figure 2: The influence of the end wall top plate radius.

maximum electric surface field over the accelerating field and the ratio of maximum surface B field to accelerating field decreases in the same way. For the B field, an approximate analysis can be made as follows: suppose the spoke cavity can be regarded as an LC circuit, at resonance, we have

$$\left.\begin{array}{l}\left.\begin{array}{l}CU^2 = LI^2 \\ \omega = 1/\sqrt{LC}\end{array}\right\} \rightarrow I = \omega CU \\ \qquad B \propto I\end{array}\right\} \rightarrow B \propto \omega CU \quad ,$$

where frequency ω and voltage U are constants. From this relation we can see that when the capacitance C decreases, B field will decreases too.

Second, when changing the racetrack thickness, a minimum ratio of the maximum electric surface field to the accelerating field can be located. The optimal value of the racetrack thickness is 2.95cm in our case, which is a little less than 1/3 of the accelerating length [2], as can be seen in Fig.3.

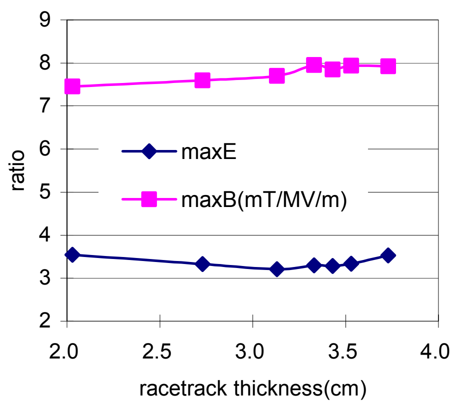

Figure 3: The influence of spoke racetrack thickness.

As for the variation of the end-wall bottom radius and the spoke racetrack width, the maximum surface electric field and magnetic field changed in different direction. According to the minimum of the product of those two, the optimal value is determined.

When the spoke base radius varies, the maximum surface magnetic field appears a minimum value, as shown in Fig 4. At same time, the maximum electric field is slightly decreased.

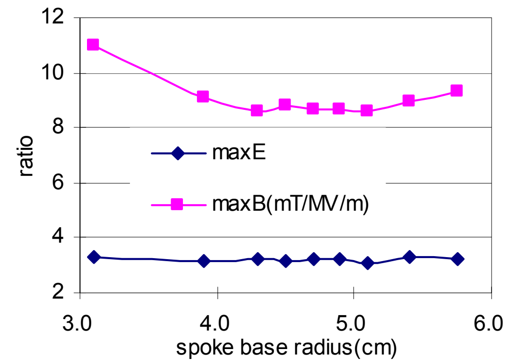

Figure 4: The influence of the spoke base radius.

Also the influence of the chamfer radius of the cavity and spoke is calculated. It seams that when the chamfer radius is 2.5cm, both the electric and magnetic fields reach a minimum at the same time.

In the table 1, the final main parameters of the spoke cavity are listed. The chamfer radius of beam tube and cavity is 0.8cm, and of beam tube and spoke is 1cm.

The main RF parameters are listed in Table 2.

Table 2: The major RF parameters of the spoke cavity

Q_0 (Rs 70 nΩ)	$8.6*10^8$
T (@0.175)	0.759
Bpk/Eacc(mT/MV/m)	7.35
Epk/Eacc	3.18

SUMMARY

The influence of the geometric parameters of racetrack type spoke cavity on B_{pk}/E_{acc} and E_{pk}/E_{acc} is studied in detail. In next step, we will conduct the mechanical design on the spoke cavity.

REFERENCES

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