A NEW STRUCTURE COMBINING LOW DIMENSIONS OF THE FOUR RODS AND TECHNICAL ADVANTAGES OF THE FOUR VANES

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Abstract

To reduce the cavity transverse section at low frequencies, people use to increase the inductance using the longitudinal direction (coaxial RFQ). In the four rods cavity, the electrical current goes longitudinally in rods supports. The disadvantage of this technique is the increased power deposition in these supports. The proposed geometry is derived from the four vanes technology. The vanes are identical near the beam but asymmetrically cut near the bottom of the cavity to force the longitudinal electrical current. The benefit is a massive copper structure easy to cool and using technology and knowledge developed for the RFQ of the IPHI project. We give for an example the RF power depositions calculated with SOPRANO and mechanical deformations calculated with IDEAS of the design performed in favour of the SPIRAL II project (LINAG).

1 INTRODUCTION

In favour of the SPIRAL II project [1], the CEA accelerator service has studied an injector for Z/A of 1/3 to 1/2. The LINAG (LINac At Ganil) injector aims to accelerate 1 mA of Z/A of 1/3 and 5 mA of deuterons up to 0.75 MeV/A in CW mode. The accelerator is composed by ECR sources, low energy beam lines, a RFQ and SC Quarter Waves Resonators [2]. Taking into account the present state of art for SC low betas cavities and beams dynamics considerations (RFQ for Z/A=1/3); a frequency of 87.5 MHz has been chosen.

For such frequency, people use to operate with coaxial RFQs which induces smaller cavities than classical four vanes. This kind of RFQs is more power consuming and produces high peak surface power on rods supports (mechanical stress). This problem is less detrimental for low duty cycle. For high duty cycle, CW and frequency bigger than ~150 MHz, compact copper four vanes RFQ are used. The mechanical advantages are well known: a strong thermal inertia and a minimisation of the peak surface power. The main drawback is the cost at low frequency. The 2D inductance-capacitance circuit induces a big transverse section. This paper details an alternative structure which aims to combine the advantages without the drawbacks of coaxial and four vanes RFQs.

2 RADIO FREQUENCY STUDY

The geometry is very similar to four vanes extremities. The vanes are hollowed out as the classical undercuts at 4 vanes exit (see figure 1). To maximise the inductance without an increase of transverse section, undercuts are asymmetrical between vertical and horizontal planes.

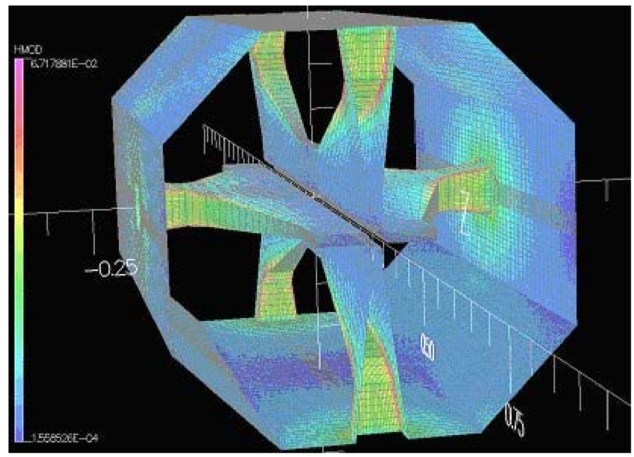

Figure 1: 3D view of the cavity (magnetic map)

The cavity performances have been computed using the SOPRANO module of OPERA [3]. The table 1 sums up the main results. Energy and powers values have been calculated with a 20% margin.

Table 1: Main parameters of the cavity.

Parameter	Units	Value
Frequency	MHz	87.5
Length	m	6.876
Stored energy	Joule	4.65
Copper power	kWatt	223.6
Beam power	KWatt	7.78
Quality factor	∅	11543
Shunt impedance	kΩ.m	148.8
Peak surface power	W/cm^2	29.77
Peak field	MV/m	17

The power consumption is compatible with existing RF power sources (230 kW). The quality factor is slightly higher than coaxial RFQs ones (11543 compared to

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~9000). The shunt impedance is better than built RFQs at such frequency (149 kΩ.m compared to ~110 kΩ.m) [4]. Figure 2 shows the distribution of the power on the cavity surface. The peak value is equal to 24 W/cm^2. This value is the same order of magnitude than IPHI RFQ. It is relatively low compared to typical values for four rods close to 100 W/cm^2.

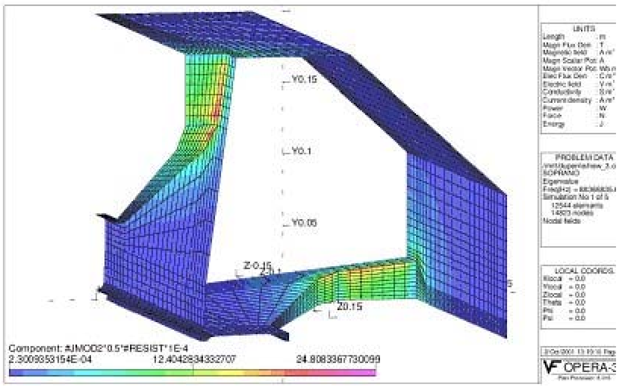

Figure 2: Peak surface power on supports (24 W/cm^2).

The mean radius of the cavity is equal to 20 cm. This value is the same order of magnitude than coaxial RFQs for 87.5 MHz [5]. These simulations shows that the performances of this cavity are close to combine advantages of coaxial and four vanes RFQs.

3 MECHANICAL STUDY

3.1 Structure

In accordance with the previous section, the vanes of this alternative structure looks like vanes of the usual « 4 vanes » with an opening in them like the picture 3 shows.

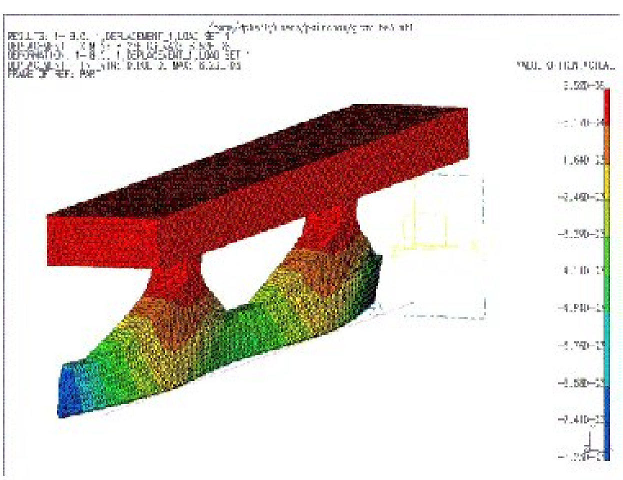

Figure 3 : Deformation of opening vane due to gravity. (Horizontal vane)

Bases of vertical vanes are one half step shifted in front of bases of horizontal vanes. Of course, brazing plans can't be shifted. So, elementary pieces are of two types like described on the figure 4.

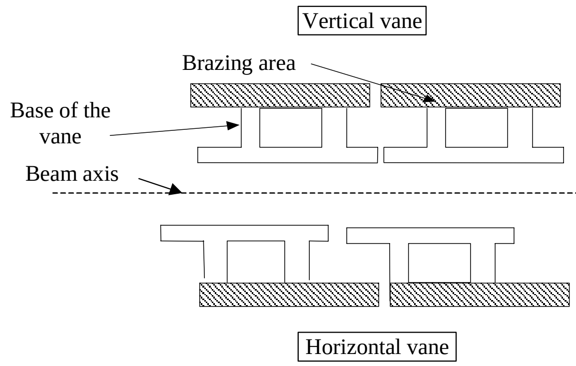

Figure 4: Cut the sections.

In our particular case, length of the elementary step is 275 mm. We want for machining profitability, pieces length between 1 meter and 1,5 meters. A typical length of 1375 mm, multiple of 275 mm, is a good solution.

3.2 Thermo mechanical point of view.

The thermo mechanical study is based on the same principles than for the usual "4 vanes": The thermal expansion of the cavity bottom makes up for the thermal expansion of the vane. On another side, we can also have a cooling temperature lower than the machining one.

But, there is a significant difference. Just one area has an important thermal power deposit: The base of the vanes. In comparison, the power deposit on the other parts of the cavity is very low. So, to regulate the cavity we propose to put warning channels all around the bottom of the cavity. We would increase the thermal expansion of the external circle with the value needed by the thermal expansion of the bases of the vanes. So, position of the vane tip will be constant.

This solution is correct only if thermal expansion of the vane bases are not too great. To roughly evaluate this idea, we do a first calculation based on the thermal density given by the code Vector Field with a security factor of 2: 50 W/cm^2.

The order of value of the convective coefficient is 3 W/cm^2/K. Conductive coefficient is 4 W/cm/K applied on an 5 mm thickness. If the ratio between the cooling surface and the heating surface is 1, the gradient of temperature between the cooling channel and the hot point can be evaluated in 1D: We obtain 20°C. If the cooling temperature is 10°C, the increase of temperature taken in account the thermal expansion is 10°C which produce an expansion of 10 µm. There is no obvious impossibility.

To decrease the resonant frequency with the smallest size of cavity, vanes have to be the thinnest as possible. Consequence is a transverse deformation of the horizontal vane. Calculations give 8 µm as shown on figure 3. This is perfectly acceptable by the beam dynamics.

4 CONCLUSION

A new RFQ structure combining advantages of four rods and for vanes is proposed. The main drawback is that the power consumption is twice higher than "pure" four vanes resonators (four rods behaviour). This is why it is relevant only for low frequency. At higher frequency, required power increases and power sources are more and more expensive.

The mechanical simulations shows that the tolerances in the beam zone are very close to tolerances obtained for 350 MHz RFQ such as LEDA or IPHI which are very sensitive to errors. This gives interesting margins for machining and cost.

5 REFERENCES

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