MECHANICAL DESIGN OF TRIPLE SPOKE CAVITY FOR EURISOL

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Abstract

Within the framework of the EURISOL (European Isotope-Separation-On-Line facility) programme, supported by European Union, IPN Orsay has proposed a 352MHz triple-Spoke superconducting cavity: for the intermediate energy section ($\beta = 0.3$) of high power proton linear accelerators.

In terms of structure design, a triple-spoke superconducting cavity has a complicate geometry, 3D modelling is necessary. More, the design require simulations which couple electromagnetic with mechanics.

To perform these tasks, the mechanics simulation code CAST3M (Calcul et Analyse de Structure et Thermique par la mthode des Elments Finis) [1] has been linked to the electromagnetics code Opera3D [2] via a dedicated plateform, which has been developed for this purpose. This work allows the instantaneous passage from CAD (CATIA) design to mechanical calculations using Cast3m and electromagnetical simulations with Opera3D. As a consequence, the deday of design studies has been considerably reduced.

The electromagnetics and mechanics behaviours of the triple are presented and discussed in this paper.

INTRODUCTION

Superconducting (SC) RF cavities have a high efficiency accelerating gradient and bore aperture. This technology is also expected to be advantageous in a linear accelerator in terms of power consumption, construction cost and beam loss. Although this conclusion is well accepted for the high energy part of the accelerator, it is still challenging at low energy. A 352 MHz triple Spoke cavity (triple Spoke cavity) has been proposed by IPN Orsay for the low beta ($\beta = 0.3$) sections of the proton linac in the Eurisol project [3]. Meanwhile, the study of a 352 MHz ($\beta = 0.48$) triple Spoke cavity for the HIPPI project [4] has been achieved and also referenced for Eurisol triple Spoke cavity design. The classical mechanical design uses CAD computer design (Catia at IPN Orsay). The original platform [5] which links Catia to the electromagnetic optimization code Opera-3d and the mechanical code Cast3m has been used to couple 3D simulations.

FROM RF TO MECHANICS

The RF design of the 352 MHz $\beta = 0.3$ multi-Spoke superconducting cavity takes into account physics requirements (beam energy and acceptance) in order to reach the highest accelerating efficiency (minimum ratio E_{pic}/E_{acc}, B_{pic}/E_{acc}). The inner shape of the cavity has been optimized in order to get a best ratio between maximal electromagnetic field and accelerating field [6] on the cavity surface. As the same times, the electromagnetical field distribution has been simulated with Opera3D/Soprano in order to perform coupled electro-mechanical simulations. The figures 1 and 2 show the electromagnetics fields.

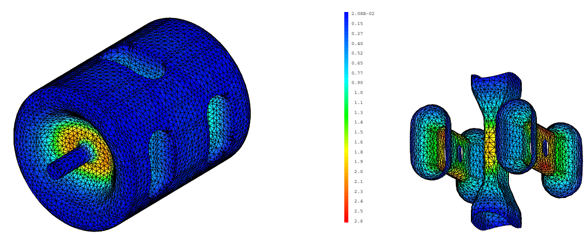

Figure 1: Electric field

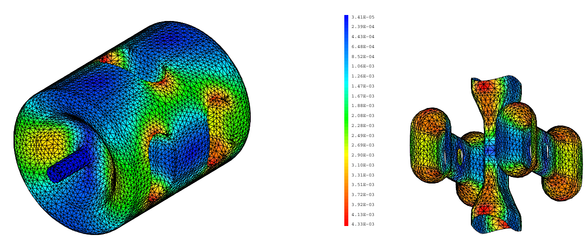

Figure 2: Magnetic field

Coupled with electromagnetical simulations, the mechanical simulations have been performed to evaluate freqency shift due to Lorentz forces, figue 3. The coupled electromechanical simulations allow also to design power coupler port and pick up ports. Many mechanical simulations have been carried out to optimize the cavity wall thickness choose the adapted stiffeners and all the supports of the cavity, especially to guarantee the cavity integration with its cold tuner into the helium vessel.

Since another important criterion of the mechanical design is the high cost of niobium: minimization of the thickness is required. Starting from a 3 mm wall, mechanical simulations using Cast3m showed that the maximum Von Mises stress level under 1 Bar pressure exceed 50 MPa which is the elastic limit of niobium at room temperature.

In order to reduce the stress level at the front part of the cavity, the solution consists, on one hand, in increasing the

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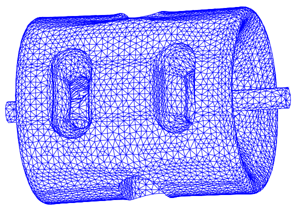

Figure 3: 3D deformation due to Lorentz forces: $< \mu m$, amplify scale: 5000

thickness of cavity wall up to 5mm in this region keeping the thickness to 3mm elsewhere and, on the other hand, in adding a stiffener on each conical end cell. The figure 4 shows the final Van Mises stress distribution, the stiffeners smoothing the stress of front part of cavity and reducing consequently its peak value.

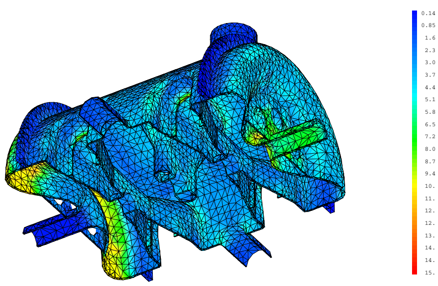

Figure 4: Von Mises stress distribution, unit: MPa

From simulations results, we have see a big difference of stress distribution on unstiffened or stiffened cavity. For an unstiffened cavity, the critical region where stress peak is located is arrond the iris, the maximum stress is 48 MPa. While for a stiffened cavity, the stress is more uniformelly distibuted, the stress peak is located at the junction between stiffening rings and the cells, also between end cells and beam tube. The Van Mises stress level don't exceed 32 MPa.

INTERGRATION TO THE HE TANK

On the cylindrical part of outer wall of the Spoke cavity, two niobium rings are welded to the helium tank in order to stabilize the cavity. This solution has big advantage to increase the first mechanical vibration mode of this cavity. In table 1, the importance of using fixing rings is shown: it eliminates a large range of low vibrations modes.

The principle of cavity cold tuning is based on micrometric longitudinal deformations of the cavity wall, made by a mechanical tuner. Such deformations allow to correct the frequency shift. For this purpose, one end of the beam tube is not attached to the tank and the tuner system pushes the outside of the tank on this side. Thanks to the rings which link the cavity's cylindrical wall to the tank, the mechanical deformations under pressure take place mainly

Table 1: Mechanical modes comparison

mode	Beam tube fixed	fixation by ring between cavity and tank
1	$5Hz$	$296Hz$
2	$14Hz$	$361Hz$
3	$15Hz$	$497Hz$
4	$16Hz$	$505Hz$

on the conical end cell. The figure 5 show the Von Mises stress distribution under 2 bars on the cavity integated in the helium vessel.

Simulations have been also performed in order to integrate an existing tuner, some adaptations were necessary. Four intermediary blocks, have been optimized in order to minimize the displacements of the front part of the tank.

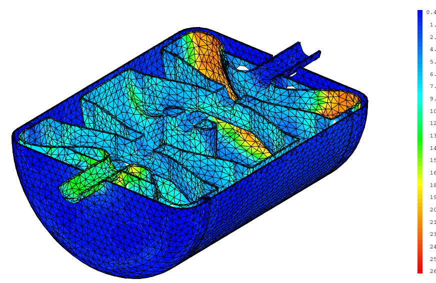

Figure 5: Von Mises stress distribution on the cavity integrated in its helium vessel, unit: MPa

PROTOTYPE

After the mechanical optimization, the engineering drawings have been achieved with Catia. The output of CAD describes not only the dimensioning for manufacturing but also all information such as materials, tolerances, processes and some specific conventions. The final engi-

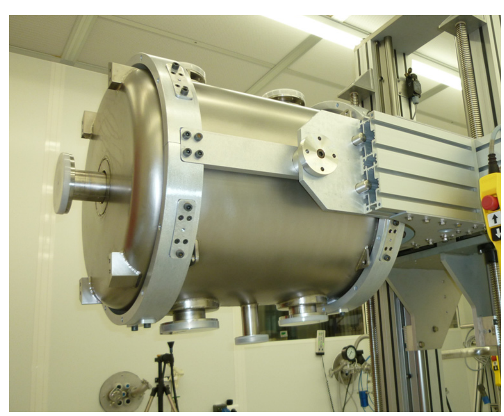

Figure 6: Prototype of β = 0.3 triple Spoke cavity integrated in its He tank

neering drawings were elaborated in collaboration between IPNO and the industrial company SDMS. The prototype is now manufactured, figure 6. The tests of this prototype are expected to take place in some months. The future RF tests have to check up both RF performance and mechanical behaviours.

CONCLUSIONS AND PERSPECTIVES

The low beta (β = 0.3) 352MHz triple Spoke superconducting cavity has been designed at IPN Orsay. The original shape of this triple Spoke gives more mechanical constraints compared to the beta 0.65 triple Spoke cavity working at the same resonance frequency. As a consequence, the mechanical design includes original solutions for this challenging cavity concept. The test of prototype is scheduled in 2011.

ACKNOLEDGEMENTS

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