OPTIMIZATION OF WALL THICKNESS OF SUPERCONDUCTING 700 MHZ BULK NIOBIUM AND NIOBIUM COATED OFHC COPPER CAVITIES BY THERMAL/STRUCTURAL ANALYSIS

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INTRODUCTION

- The Thermal\Structural Analysis has been carried out on a prototype single cell Superconducting elliptical cavity of $\beta_g = 0.42$ at a frequency of 700 MHz using COSMOS/M.
- To operate it at low temperature, the cavities are cooled down from 300 K to 4.2 K in a liquid He bath.
- The deformation and the effective stress has been analyzed under the thermal load and the inward He-I pressure of 1.013E+5N/m2.
- Resonant frequency shift due to the structural deformation is calculated using CST MICROWAVE STUDIO/ SUPERFISH code.

MODELLING OF THE CAVITY

- A 45^0 section of the cavity including the beam tube has been modeled and shown in FIG-1.
- The general boundary conditions are also shown in FIG-1.

- Model has been generated for both bulk Nb and Nb coated Copper cavities.

- The material properties used for both the structure are listed in Table-1.
- A nonlinear variation of thermal conductivity and specific heat has been taken into account for both the types of cavities.

- the thermal conductivity of Nb (RRR250) as a function of temperature can be written as,

$$K_{Nb}(T) = 261.92 - 183.72T + 39.9T^2 - 1.794T^3 \quad \text{---- (1)}$$

Material Properties	Nb coated Cu cavity	Bulk Nb cavity
Young's Modulus (GPa)	110	125
Poisson Ratio	0.37	0.38
Coeff of thermal Expansion (m/K)	2.4E-5	4.9E-6
Density (kg/m^3)	8900	8570

Table-I

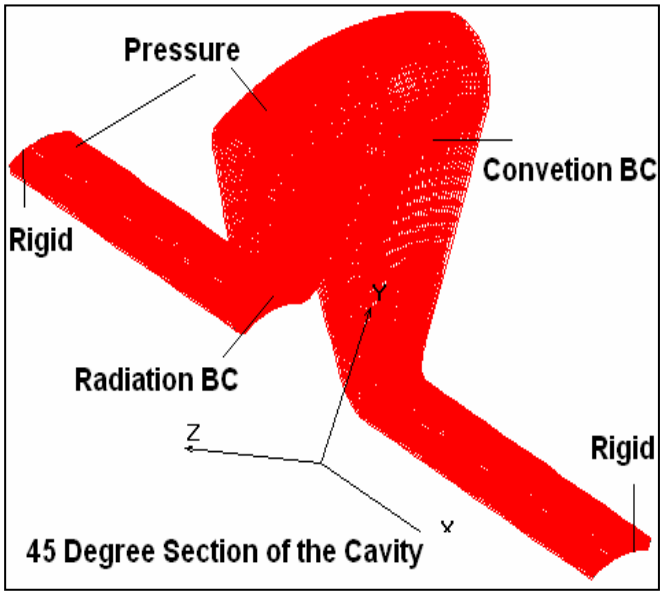
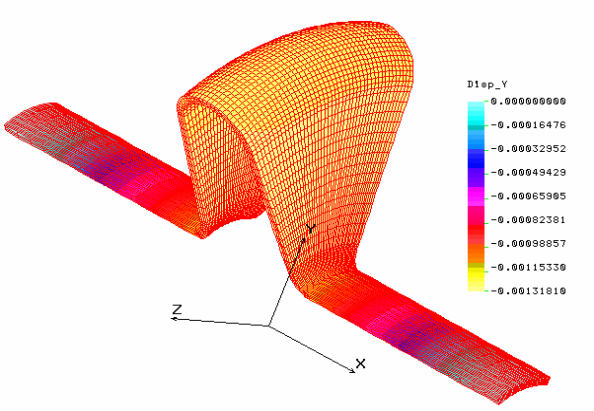


FIG-1

Thermal/Structural Results

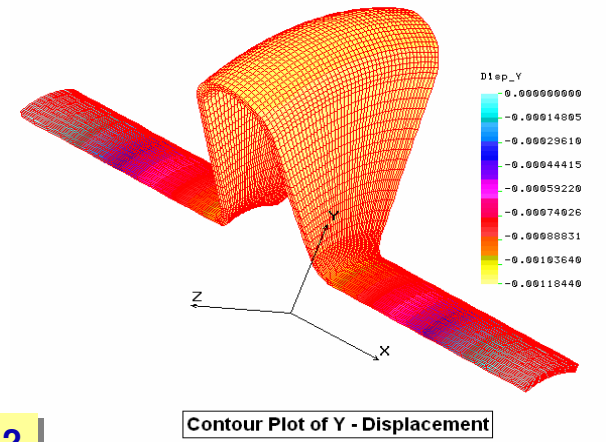
- Thermal\structural results include the helium pressure + Thermal load due to the cooling down of the cavity from 300 K to 4.2 K.
- Structural deformations was determined for different wall thicknesses of 3, 4, and 5 mm respectively.
- Typical structural deformation for 5mm thick Nb coated Cu and bulk Nb cavities is shown in FIG-2.
- FIG-3 shows the contour plot of Von-Mises stress for both the types of cavity of wall thickness 5mm.

Nb coated Cu Cavity



Contour Plot of Y-Displacement

bulk niobium cavity

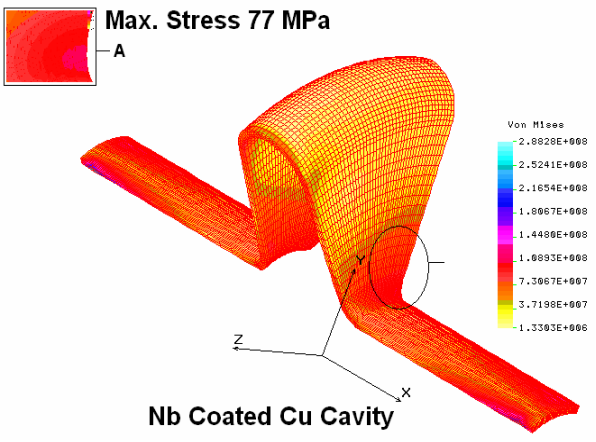


Contour Plot of Y - Displacement

FIG-2

Thermal/ Structural Results(Contnd.)

Nb coated Cu Cavity



bulk niobium cavity

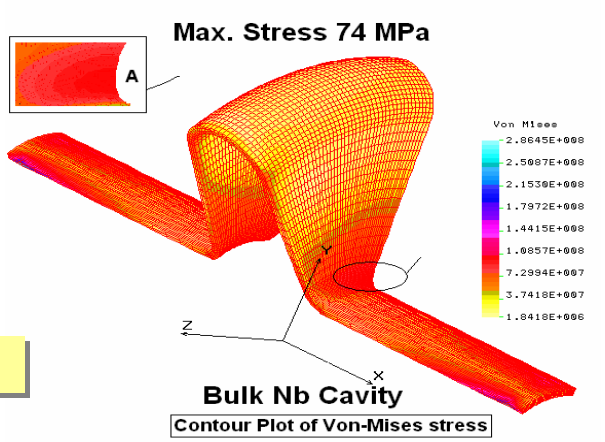


FIG- 3

➢ **A comparative study of both the types of cavity from the point of view of maximum deformations in radial and axial directions and the maximum effective stresses is represented in Table-2.**

Parameters		Nb Coated Cu Cavity	Bulk Nb Cavity
Yielding Stress MPa		261- 441 MPa	700MPa
Max Von-Mises Stress MPa	3mm	106	104
	4mm	91	88
	5mm	77	74
Y-Diplacement mm	3mm	-2.850	-2.534
	4mm	-1.873	-1.676
	5mm	-1.312	-1.182
X-Displacement mm	3mm	-0.418	-0.363
	4mm	-0.252	-0.216
	5mm	-0.156	-0.141

Table- 2

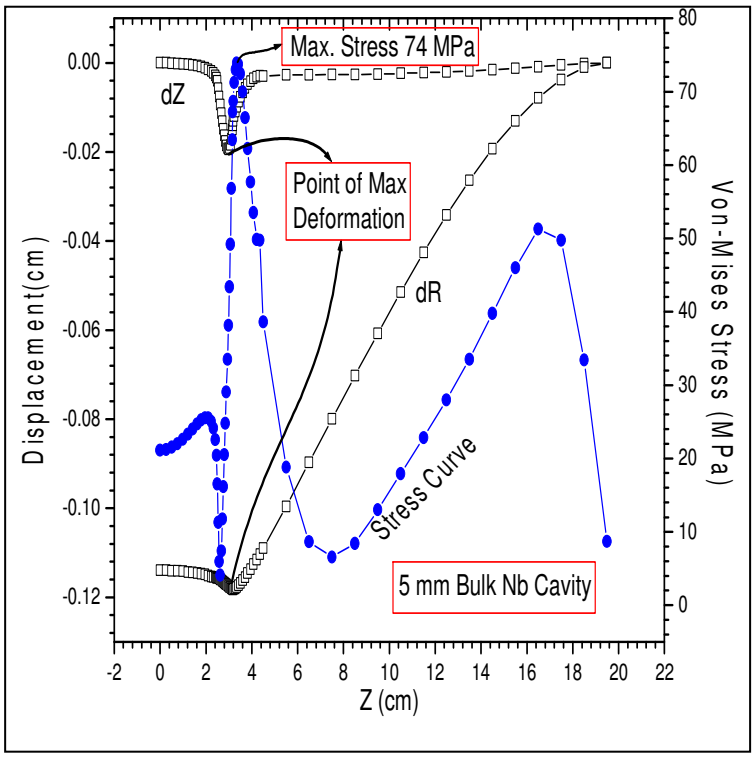


FIG- 4

➢ **So from the stress point of view all the thicknesses analyzed are suitable.**

RF PROPERTIES

- The RF properties of the deformed models have been calculated using SUPERFISH and CST- Microwave Studio and shown in Table- 3.

Table- 2

Thickness (mm)		Parameters	Undeformed	deformed
3	Nb+Cu	f_0 (MHz)	700.002	705.198
		T	0.7817713	0.7818218
		E_{pk}/E_0	1.9725	2.0271
		B_{pk}/B_0	4.1528	4.2723
	Nb	f_0 (MHz)	700.002	704.646
		T	0.7817713	0.7818164
		E_{pk}/E_0	1.9725	2.0088
		B_{pk}/B_0	4.1528	4.2719
4	Nb+Cu	f_0 (MHz)	700.002	703.058
		T	0.7817713	0.7818010
		E_{pk}/E_0	1.9725	1.999
		B_{pk}/B_0	4.1528	4.2699
	Nb	f_0 (MHz)	700.002	702.695
		T	0.7817713	0.7817974
		E_{pk}/E_0	1.9725	1.9987
		B_{pk}/B_0	4.1528	4.2707
5	Nb+Cu	f_0 (MHz)	700.002	701.604
		T	0.7817713	0.7817868
		E_{pk}/E_0	1.9725	1.9684
		B_{pk}/B_0	4.1528	4.2633
	Nb	f_0 (MHz)	700.002	701.376
		T	0.7817713	0.7817846
		E_{pk}/E_0	1.9725	1.9645
		B_{pk}/B_0	4.1528	4.2627

- f_0 (resonant frequency), T (transit time fac), Bpk/B0 (mT/(MV/m))

CAVITY MODEL WITH STIFFENER AND ITS EFFECT

- A conical stiffener has been incorporated and analyzed with respect to the different positions at the cavity wall to see its effect on the frequency shift and on the effective stress value.
- At the position of (R=2.83962 cm, Z=11.801 cm), the resonant frequency shift is minimum.
- The model of the cavity of thickness 5mm with stiffener (4mm) is shown in FIG- 5.
- Computed resonance frequency shifts are 79 and 77 KHz for Nb coated Copper and bulk Nb cavity of thickness 5mm.
- The typical plot of deformation and the stress value with respect to axial distance for 5mm thick bulk Nb cavity with stiffener is shown in FIG- 6.

CAVITY MODEL WITH STIFFENER AND ITS EFFECT(Contd.)

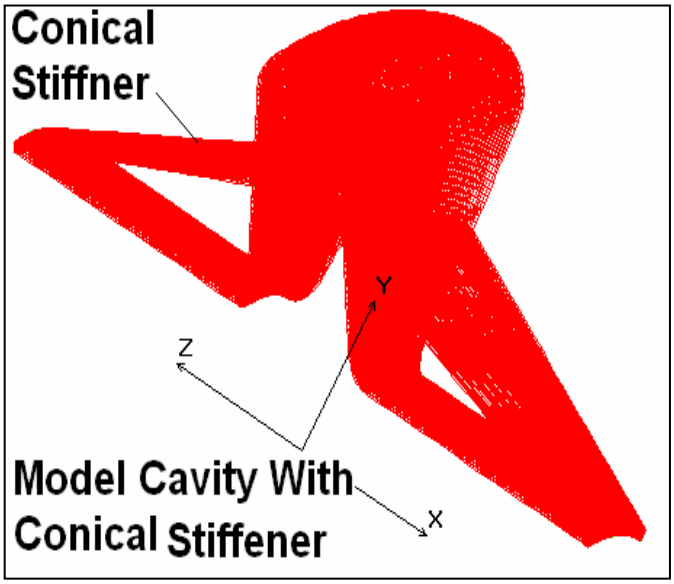


FIG-5

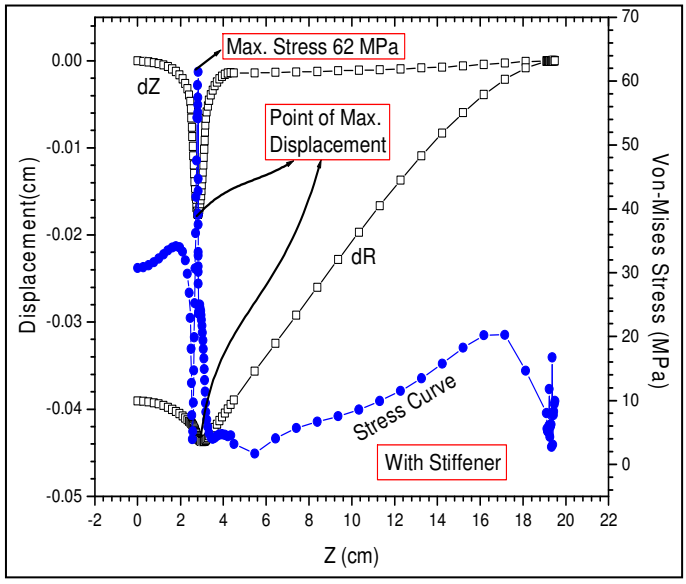


FIG-6

CONCLUSIONS

- The comparative study shows that the bulk Nb cavities have better performance than the Nb coated Cu cavities, from the point of view of Thermal\Structural and RF properties.
- For all high β cavities the optimum wall thickness is about 3mm. But our analysis shows that for low β cavities the shift in resonance frequency is significantly high for 3mm structures.
- A thickness of 5mm best replicates the RF properties at 4.2K with the original designed cavity.
- Also the 4mm thick cavity seems to be alright from the point of view of RF and mechanical properties.
- Incorporation of stiffener shows that the frequency shift comes down to few tens of KHz.