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Introduction to Heat Flux Loads Calculations Due to Electromagnetic Radiation Inside the 805MHz Test Cavity

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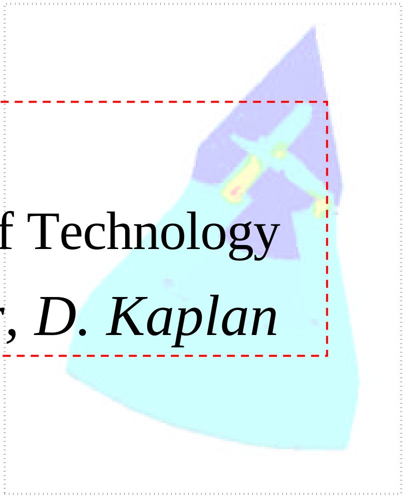

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I. OUTLINE

I. Introduction

II. Sample problem : Thermal analysis of a symmetric pillbox cavity/ analytical and numerical solutions

III. Thermal analysis of the 805MHz cavity:

- Be windows from both ends
- 4x4 grid configuration without cooling
- 4x4 grid configuration wit helium gas cooling

IV. Present and future work

Questions during the presentation or after: Please call (312) 437-5454 or e-mail alshmoh2@iit.edu

I. INTRODUCTION

- Cavity model has a Be-window from one side and a grid of tubes from the other side that is built in place of the other Be- window at the same location.

- Current objective is to perform thermal analysis of the cavity with the grids.

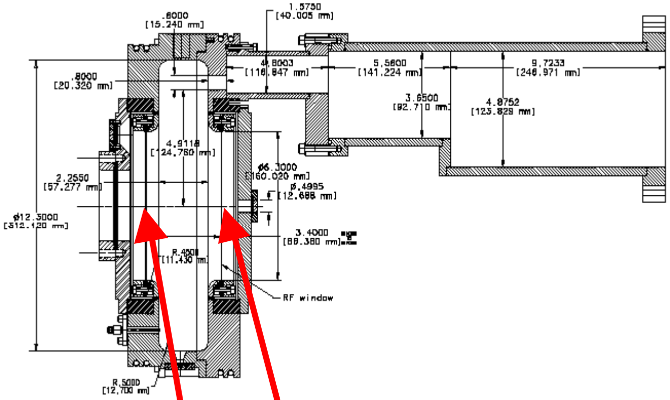

Fig. 1: *Cross-sectional view of the 805 MHz cavity*

Design variables:

1) grid spacing
2) tube outer diameter
3) number of tubes
4) number of grids
5) tube wall thickness
6) type of coolant and coolant flow rate

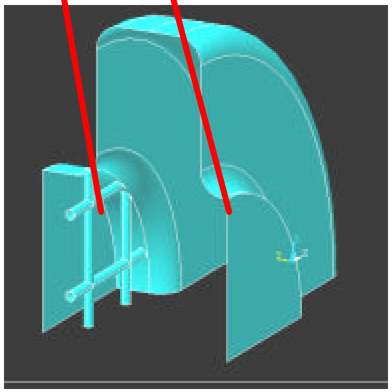

Fig. 2: *ANSYS model*

- Power Loss due to the electromagnetic radiation Inside the cavity

$$Ps = \frac{1}{2} \int_{s} R_s H^2 .dA \qquad R_s = \sqrt{\frac{pfm_0}{s}}$$

- Scaling factor for the heat flux loads=Average power loss in the cavity (500W) /Normalized power loss (calculated)

- Lab. G tests/ Fermi:

Duty factor (D)= 0.025% , On-axis acceleration field Ez(0)=30MV/m

- Previous concern was to find a grid with manageable tube surface field enhancement. Present focus is thermal analysis of the cavity with the grids.

- To check grid thermal analysis results, an 805MHz cavity sample is presented next with analytical and numerical thermal solutions.

II. SAMPLE PROBLEM

Analytical solution

$$w_{010} = \frac{2.405}{\sqrt{m_0 e_0}\,b}\ , \quad f = \frac{2p}{w_{010}} = 805MHz$$

$$E_z = E_0\, J_0\left(\frac{2.405r}{b}\right)$$

$$H_f = -i\sqrt{\frac{e_0}{m_0}}\,E_0\, J_1\left(\frac{2.405r}{b}\right)$$

$$Ps = \frac{1}{2}\int_s R_s H_f{}^2 .dA \qquad R_s = \sqrt{\frac{pfm_0}{s_{\ w}}}$$

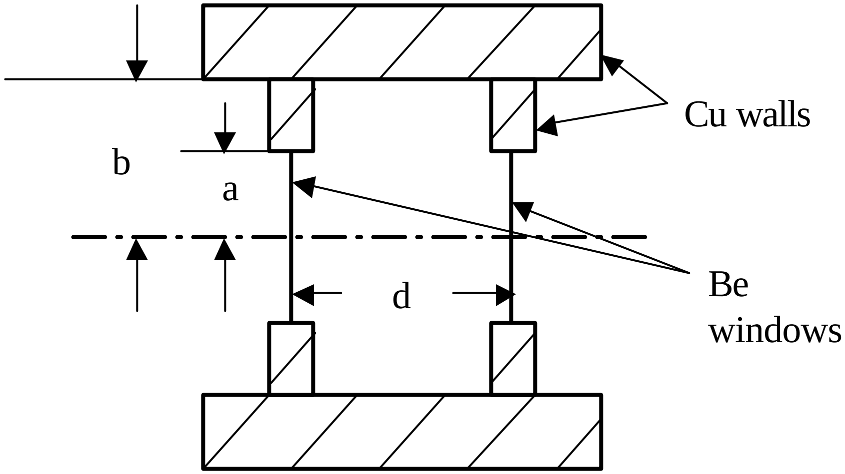

Fig. 3: *sketch of the sample 805MHz cavity*

Power loss $P(r) = Dp\,\frac{R_s}{2}\,\frac{e_0}{m_0}\,E_0{}^2\left[r^2 J_1{}^2 + r^2 J_0{}^2 - \frac{2rJ_0 J_1}{(2.405/b)}\right]$

Heat Flux $F(r) = D\frac{R_s}{2}\,\frac{e_0}{m_0}\,E_0{}^2 J_1\left(\frac{2.405r}{b}\right)$

Parameters

a=8.000cm

b=14.255cm

d=7.794cm

t=0.127mm

k=216.0w/mk

Using Fourier heat conduction law

$$Q = -kA\frac{dT}{dr}$$

The temperature distribution is obtained as

$$T(r) = -D\frac{R_s}{4tk}\frac{e_0}{m_0}{E_0}^2\left[r^2{J_1}^2 + r^2{J_0}^2 - \frac{rJ_0J_1}{(2.405/b)} + \frac{r({J_0}^2-1)}{(2.405/b)^2} + C1\right]$$

Boundary condition: Temperature is specified at the ring of the Be window as T(r=a)=Ta

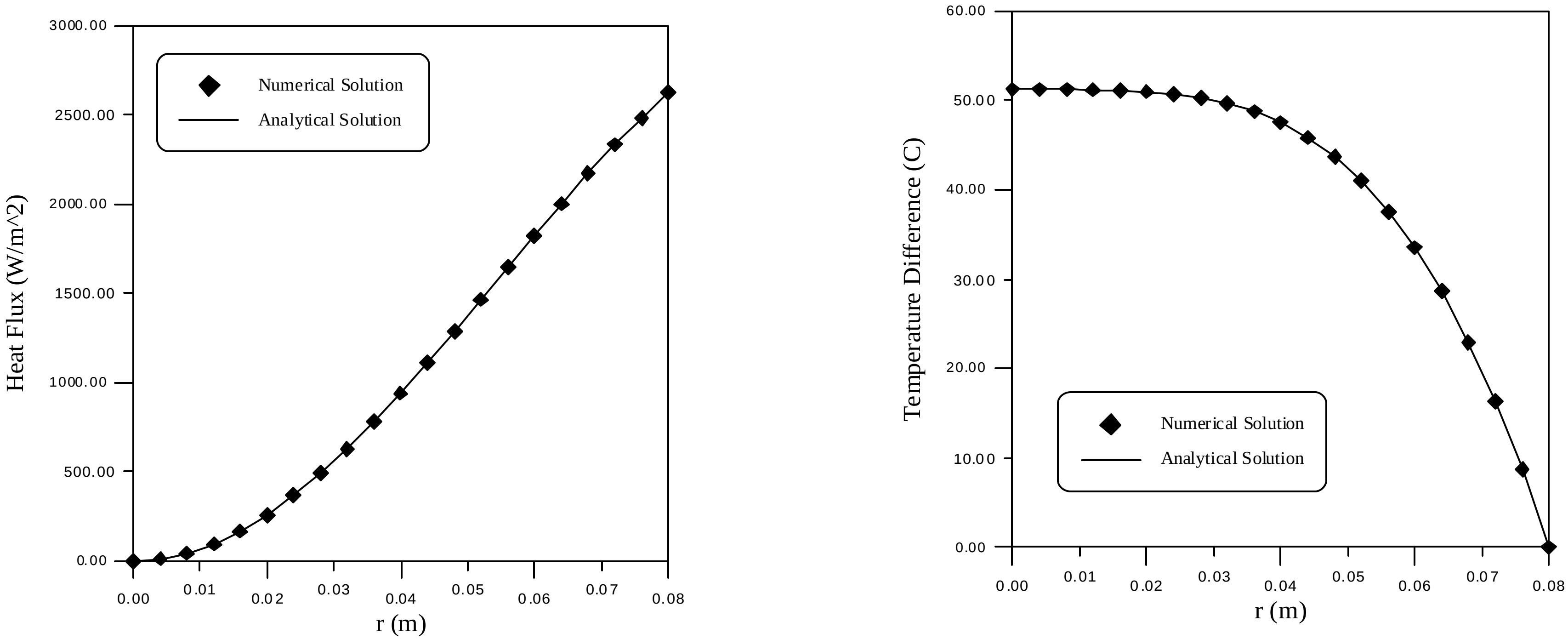

Fig. 4: *heat flux loads and temperature as function of radius. Temperature values are the difference from the ring temperature* T_a

III. THERMAL ANALYSIS

805MHz cavity closed by Be windows from both ends

1/8 model is considered

Boundary condition: Temperature at the outer surfaces =room temperature=0.0, so the temperature solution presented is a difference from the room temperature. This is applied for all the other cases.

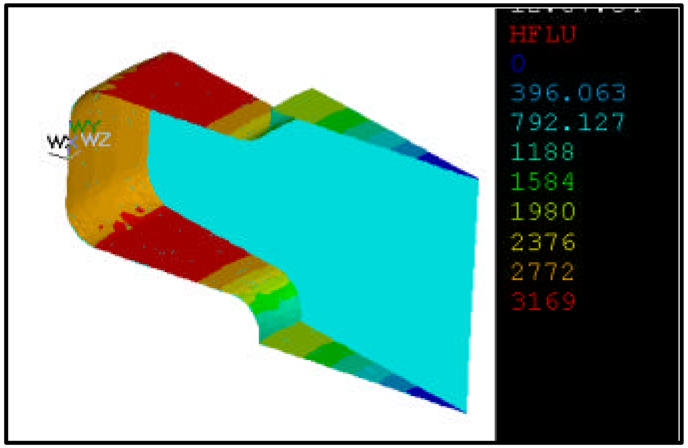

Fig. 5: *Heat flux loads (w/m^2)*

The hottest region is at the center because the center is the farthest from the cooling boundary condition, so heat loss by conduction at the center is less than that of other regions

Material properties

	Electric cond. (ohm.m)$^{-1}$	Thermal cond. w/m.k
Al	0.250e8	166.9
Cu	0.588E8	385.0
Be	0.232E8	216.0
Ti	0.0181e8	17.0
SS	Not needed	12.1

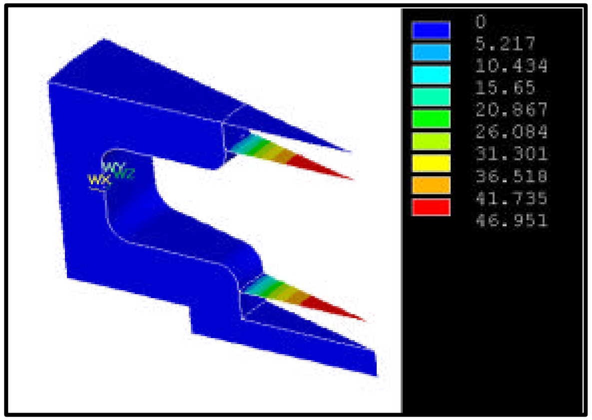

Fig. 6: *temperature at the different parts*

805MHz cavity with a 4x4 grid without cooling

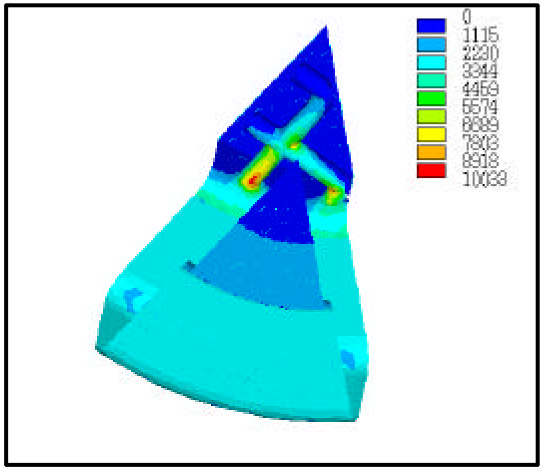

Fig. 8: *Heat flux on the different parts (w/m^2)*

Tube outer DIA: 3/8”

Tube wall thickness: 0.01”

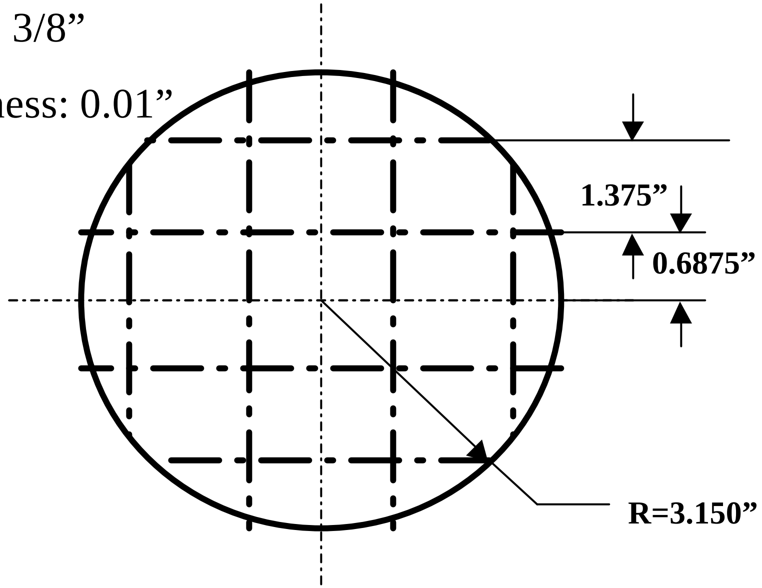

Fig. 7: *4x4 grid model*

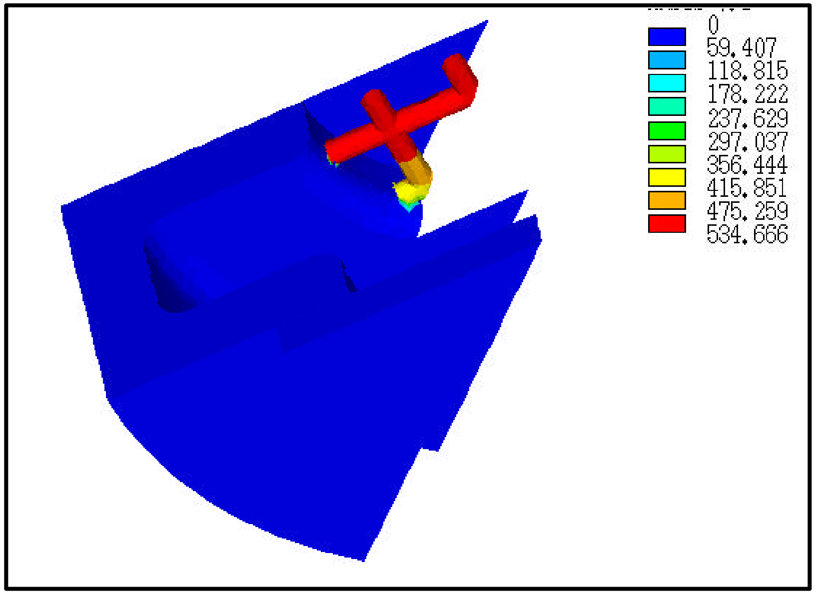

Fig. 9: *temperature at the different parts*

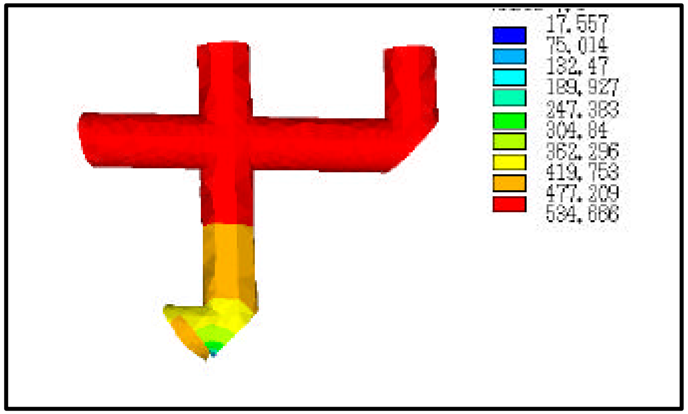

Fig. 10: *temperature at the grid walls*

805MHz cavity with a 4x4 grid with He cooling

Helium gas film coefficient was assumed to be constant at h=250w/mk

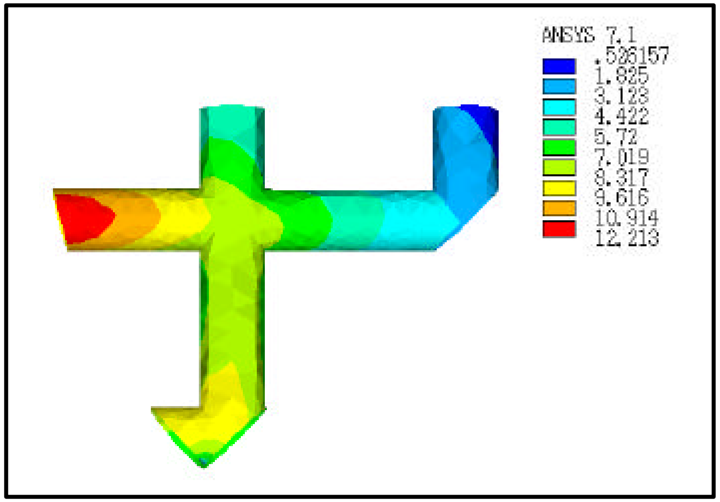

Fig. 11: *temperature at the grid walls*

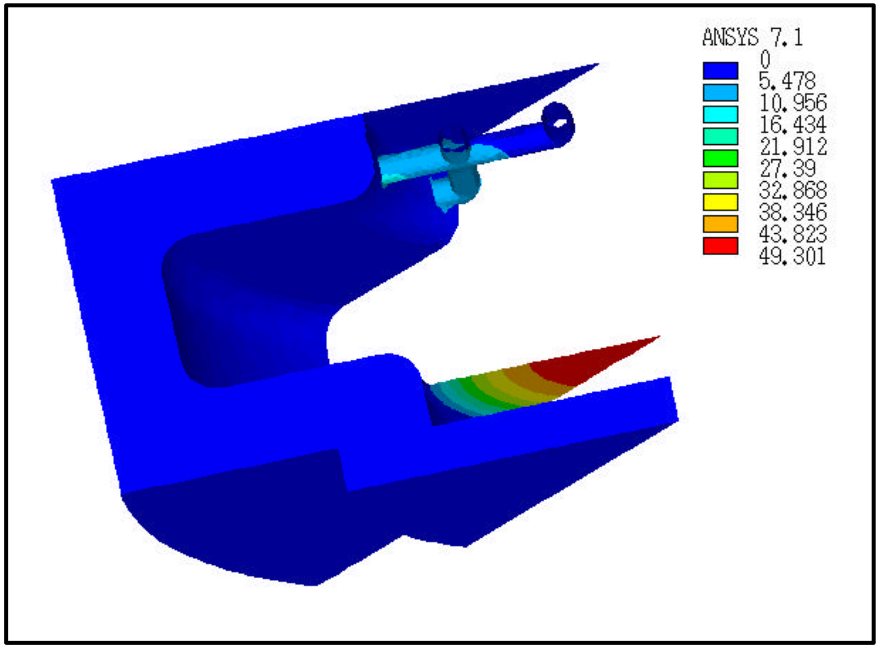

Fig. 12: *temperature at the different parts*

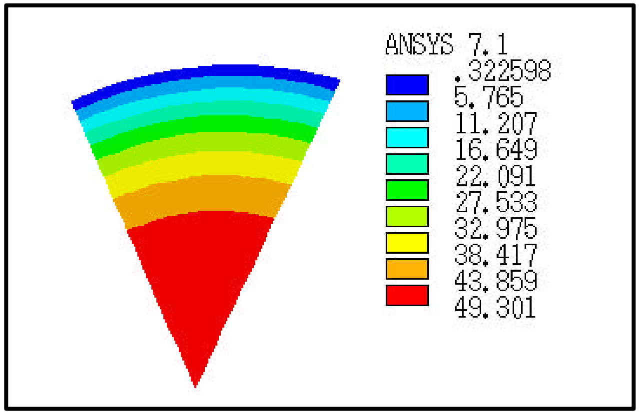

Fig. 13: *temperature at the Be window*

III. PRESENT AND FUTURE WORK

- Study of velocity and film coefficient of the coolant.
- Calculating heat flux loads on different grid configurations (6x6, 8x8,..) with different tube outer diameters and grid spacing. Change of tube wall thickness is under studied
- Calculating temperature distribution inside the tubes for the different configurations.
- Performing dynamic and thermal stress analysis for the different configurations.
- Performing electrical heating experiment of a grid sample, which may include helium cooling. Comparing heat flux loads and temperature with a corresponding FEA model.