Thermal Analysis of RF Section for 250 Kw CW C-Band Klystron

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Abstract— The paper deals with thermal management of RF-section of 250kW CW C-band Klystron. The thermal analysis of RF section has been done using ANSYS 11.0 (multi-physics) code. The thermal analysis calculates the temperature distribution and related thermal quantities in a system or component. The basis for thermal analysis in ANSYS is a heat balance equation obtained from the principle of conservation of energy. The input parameters used in thermal simulation are geometry of components, heat flux, heat transfer coefficient and output parameter is temperature profile of RF section. The RF section analysed using Poisson's Superfish, AJ-Disk and Magic 2D soft-wares to observe the electron-beam interaction in the RF-section of the Klystron. The results of these simulations i.e. R/Q, Q and the voltage across the gap of the cavity are then used to calculate heat dissipated in the RF section.

Key words: RF section; Beam interaction; klystron

I. Introduction

Klystron is basically an amplifier device, which amplifies the microwaves in terms of gain and peak output power. Klystron has various components like electron gun, window, collector and window. It is used as power amplifier in a variety of systems including radars, particle accelerators and thermonuclear reactors. During operation of klystron high power dissipated in collector, RF window and in RF section so proper thermal management is required for safe operation of the klystron. This klystron consists of an input cavity, four buncher cavities, and an output cavity. The RF signal to be amplified at the input cavity starts the velocity modulation process. Klystron is a velocity-modulated tube in which the velocity modulation process produces a density-modulated beam of electrons. The RF signal is carried from cavity to cavity by the electron beam. This klystron consists of an input cavity, four buncher cavities, and an output cavity.

A. *Specifications of the Klystron*

Operating Frequency:	5 GHz
Output Power:	250 kW CW
Beam Voltage:	50 kV
Beam Current:	10 Amp
Focusing:	Electromagnet
No. of cavities:	6
Efficiency:	40 % (min.)
Gain:	45 dB (min.)
Cooling:	Water

B. *Dimension of RF Section*

No. of cavities	6
OD of cavity	33.5mm
ID of cavity	27.5 mm
Cavity height	15.0 mm
OD of drift tube	12.5 mm
ID of drift tube	8.5 mm
Total length of RF section	337mm

II. Design of RF Cavities Using Poisson's Superfish

Poisson's Superfish is a collection of programs for calculating static magnetic and electric fields and radio-frequency electromagnetic fields in either 2-D Cartesian coordinates or axially symmetric cylindrical coordinates. The programs generate a triangular mesh fitted to the boundaries of different materials in the problem geometry. Plotting programs and other postprocessor codes present the results in various forms. We design individual Cavities and calculate their respective R/Q in Poisson's Superfish. Dimension of input and intermediate cavities

A. *Input Parameters*

Height of cavity- 15mm
Radius of cavity- 13.5mm
Height of drift tube- 5.75mm
Radius of drift tube- 4.0 mm

III. Thermal Analysis of RF Section

The thermal analysis has been done using ANSYS 11.0 (multi-physics). A thermal analysis calculates the temperature distribution and related thermal quantities in a system or component. The basis for thermal analysis in ANSYS is a heat balance equation obtained from the principle of conservation of energy. The input parameters used in thermal simulation are heat flux, heat transfer coefficient and output parameter is thermal temperature of RF section. A forced water cooled RF section has been designed to dissipate 1kW power. The temperature analysis is carried out for RF section. The temperature rise of the surface calculated for 5 l/min. to 10 l/min. flow rate. The temperature rise of the surface calculated for 5 l/min. flow rate. The desired flow rate is optimized for safe limit of temperature rise of RF section. The desired flow rate is optimized for safe limit of temperature rise of RF section. RF section has designed for 1 kW power dissipation. The output voltage obtained by AJDISK and power dissipation is calculated by this formula-

$$V^2 = .83 * 10^6 \lambda^{\frac{5}{2}} \frac{P_L}{A}$$

$$\frac{P_L}{A} = \frac{V^2}{.83 * 10^6 \lambda^{\frac{5}{2}}}$$

Using above formula we have calculated power dissipation individually for each cavity. Calculated power dissipation for first cavity is 0.106 W, for second cavity is 2.35W, for third cavity is 4.14W, for fourth cavity is 41.21W, for fifth cavity is 215 W and for sixth cavity is 689.30W. Total power dissipation for RF section is calculated 952.11W.

Heat transfer occurs between a moving fluid and solid surface. The rate of heat transfer between a surface and a fluid is given by:

$$h = \{K_w / D_H\}.N_u$$

Where K_w is Thermal Conductivity ($Wm^{-1}K^{-1}$), D_H is Hydraulic diameter (m) and N_u is Nusselt number.

A. Output Cavity Design

The output voltage of output cavity is shown in figure1 taken from MAGIC 2D code is obtained 53.4kV. Using above formula we have calculated power dissipation for output cavity is 689.30 W. and calculated heat flux and film coefficient of output cavity are 29725.10 w/m^2 and 13518.51w/m^2K respectively. These Obtained values are used as input of thermal analysis of sixth cavity. Thermal analysis of output cavity has been done using ANSYS code and we have got the surface temperature of the output cavity to be 38.02-45.02^{0}C. Temperature profile shown in Fig2.

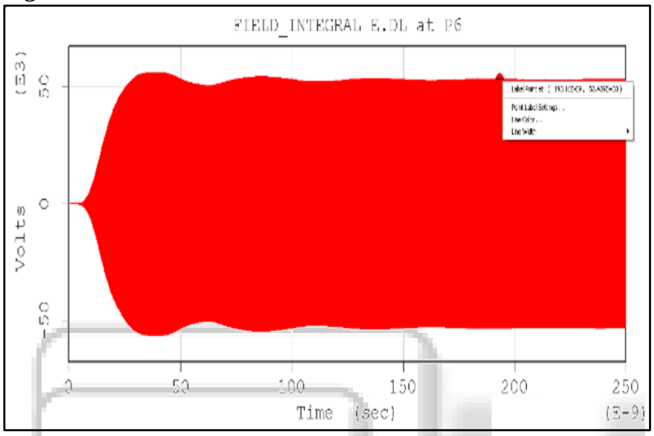

Fig. 1: output cavity voltage

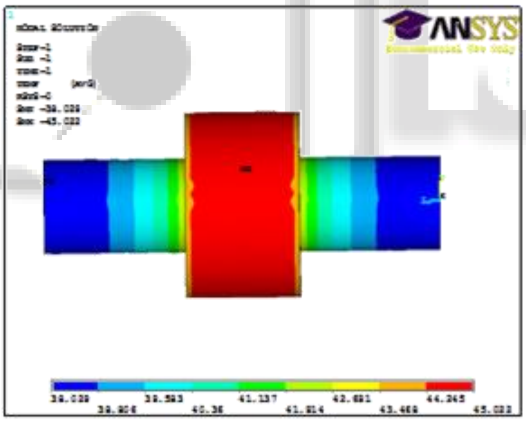

Fig. 2: Temperature profile of output cavity

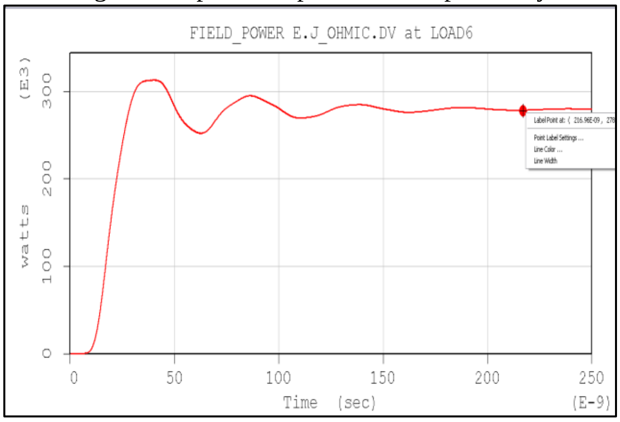

Fig. 3: Output power delivered at load

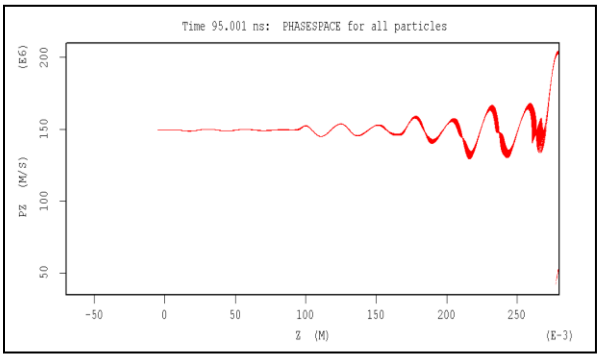

Fig. 4: Beam energy Vs axial distance

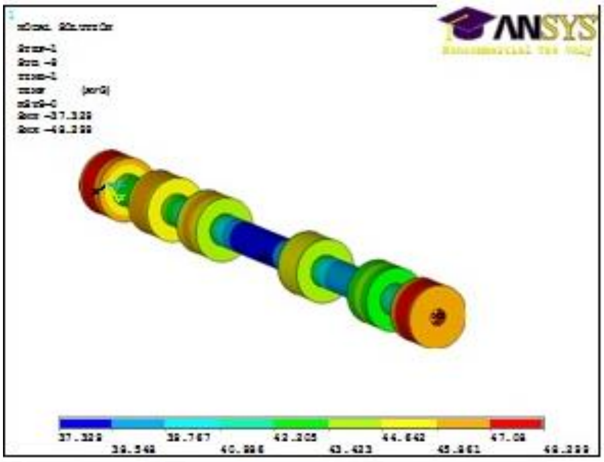

Fig. 5: Temperature profile of RF section

Water Flow(Lpm)	Applied heat flux (w/m^2)	Cooling coefficient (w/m^2K)	Simulated temp.(^{0}C) in ANSYS
5	41056.16	3518.51	37.32-48.29
10	41056.16	6126.10	33.65-39.25

Table 1: Simulated temperatures with varying flow rates:

IV. FABRICATED ASSEMBLY OF RF SECTION PARTS

Fig. 6:

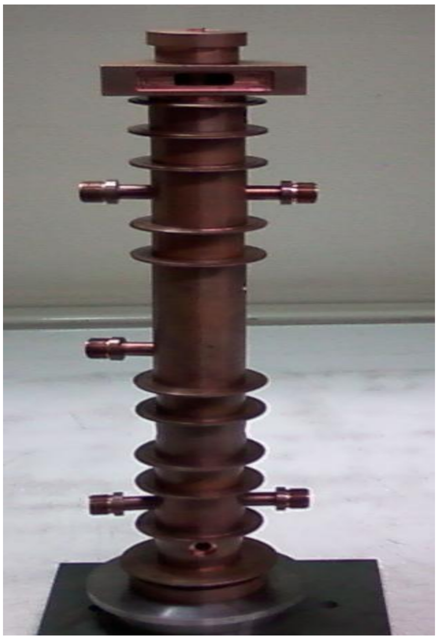

Fig. 7:

V. Conclusion

The Thermal design of RF section assembly with cooling system for 250 kW C band klystron has been done successfully**.** Thermal analysis of RF section has been done using ANSYS code and we have got the surface temperature of the RF section to be 37.32-48.29^{0}C which is quite easy to maintain. The fabrication of RF section is under progress.

Acknowledgement

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