Thermal and structural analysis of depressed collector for 42 GHz Gyrotron

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Abstract:- Thermal and structural analysis of depressed collector for 42 GHz gyrotron and the effect of structural deformation is presented. Finite element analysis codes ANSYS have been used for the thermal and the structural simulation. The values of the water flow rate and the hydraulic diameter have been optimized.
Keywords:- Gyrotron, depressed collector, thermal & structural analysis.

I. INTRODUCTION

Collector is a simple cylindrical wave-guide to collect the spent electron beam in gyrotron and dissipate the heat efficiently. In collector, the kinetic energy remaining in the spent beam after participating in the interaction process is converted into thermal energy. The energy of the beam is distributed upto certain region instead of collecting at one portion in order to avoid over heating of the collector surface. The wall loading for collector surface should not be more than 0.5 kW/cm^2 [1]. In this paper, the thermal analysis of the single stage depressed collector for 42 GHz 200 kW gyrotron is presented, which is being developed at CEERI/ India.

The depressed collector helps to increase the efficiency of the Gyrotron tube in compression to undepressed collector.

In the Gyrotrons, the electron beam is guided by the external magnetic field. In adiabatic magnetic decompression, the magnetic field is reduced sufficiently slow to allow a decrease of the transverse momentum of the electrons with decreasing magnetic field according to the adiabatic approximation of motion.

The non-adiabatic decompression method has been used to convert the longitudinal momentum of the electron into a transverse motion resulting in an increase of the larmor radius. This can be achieved with the help of additional solenoid coils in the collector region.

Material used for the collector is OFHC copper for its good conductivity and higher melting point. Thermal and structural properties of OFHC copper is given in the table 1.

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Table 1: Properties of OFHC copper used in the thermal and the structural analysis

Density (kg/m^3)	8960
Thermal conductivity (W/m.K)	334
Specific heat (J/kg.K)	385
Emissivity	0.4
Elasticity modulas (GPa)	110
Thermal expansion coefficient (per °C)	1.7×10^{-5}
Poission ratio	0.33

Thermal analysis of depressed collector.

Figure 1 shows the temperature variation due to non-uniform spreading of electron spent beam on the collector inner surface. Figure 2 shows the optimized results of the maximum beam spread i.e. 300 mm on the collector surface with a dissipation capability of 0.419 kW/cm^2 where collector radius is 42.5 mm and collector length is 800 mm [2].

When the spent beam electron strikes on the inner surface of the collector, causes excessive heating & may cause metal fatigue. To prevent the metal fatigue, proper cooling is required for the collector.

The above analysis involved for different hydraulic diameter, temperature of water and water flow rate. Different types of grooving (radial and axial) on the collector outer surface are carried out to reduce the temperature of the collector. The 3-D analysis of the collector geometry with 18 axial grooves and the wall thickness of 20 mm results into the outer temperature of about 294.8 K. Transient analysis (figure 3) shows that the inner surface temperature became steady within approx 5 second, which is safe for the operating time of this gyrotron.

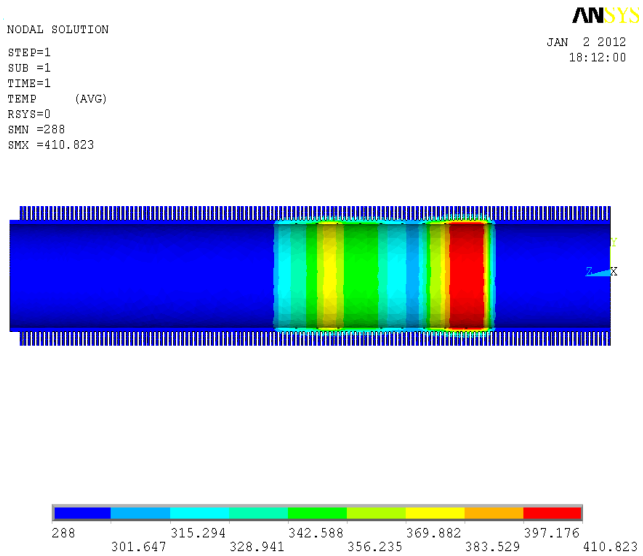


Fig. 1: Non-uniform spreading at the collector inner surface

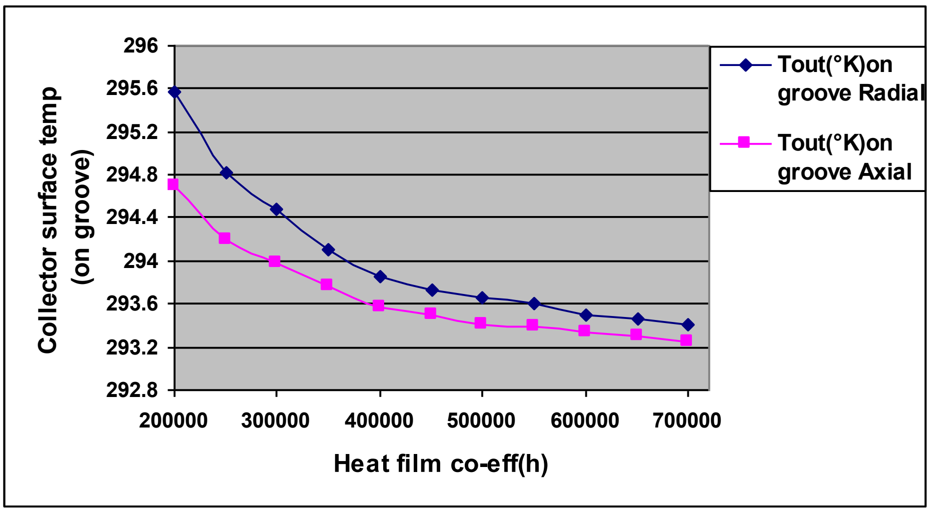
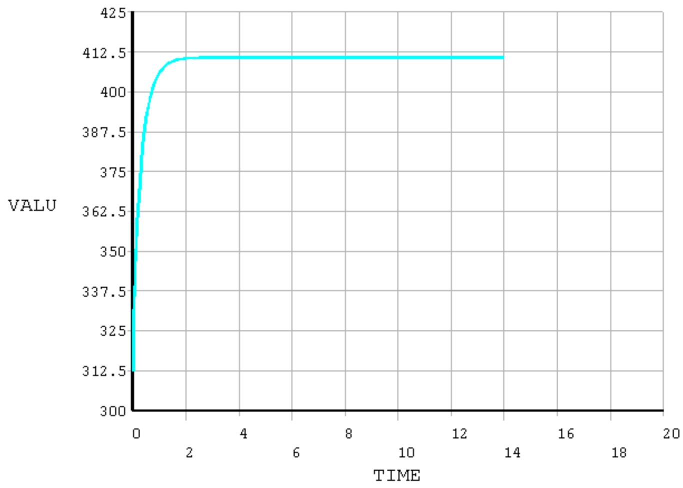


Figure 2: Variation of collector outer surface temperature with heat film coefficient for radial and axial groove.



Time(sec.)	Temp(k)
0.86843E-01	342.722
0.16426	358.228
1.9741	410.494
2.1249	410.606
2.7296	410.767
3.2296	410.802
4.7296	410.822

Figure 3: Variation of inner surface temperature with respect to time

Structural analysis of depressed collector:

The above analysis involved for different hydraulic diameter, temperature of water and water flow rate. Different types of grooving on the collector surface are carried out to reduce the structural deformation of the collector. The 3D analysis is done for the both the best case and the worst case situations.

Figure 4 shows structural deformation due to heat generated from the non-uniform spreading of the electron beam on the collector inner surface and the water flow for cooling on the outer surface. The maximum structural deformation observed is 0.125 mm which is within the safe limit [1].

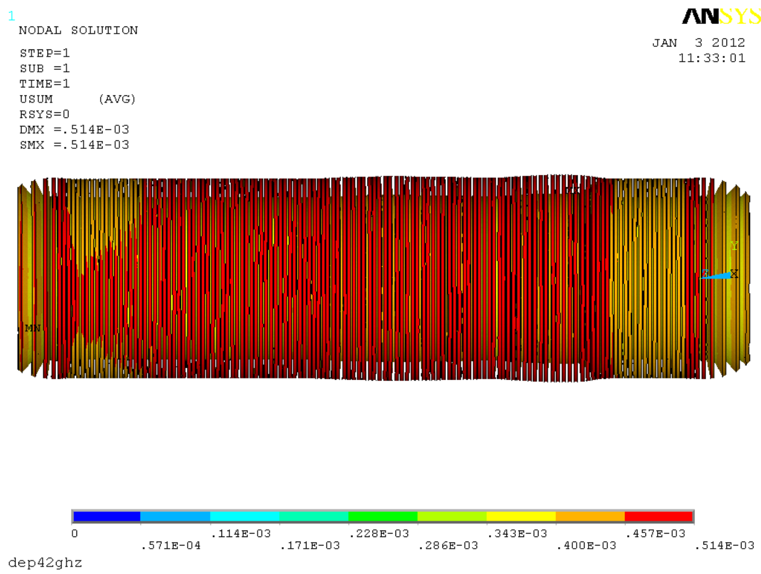


Figure 4: Structural deformation on collector surface

CONCLUSION:

The heat film coefficient has been optimized as 10^5. For this value of heat film coefficient, the optimized range of hydraulic diameter and water flow rate is 3.5 mm to 4.5 mm and 500L/min to 600L/min respectively. The radial expansion of the collector has been found 0.125mm.

ACKNOWLEDGMENT:

Authors are grateful to the Director, CEERI, Pilani, for permission to publish this paper. Thanks are due to Dr SN Joshi, Dr V Srivastava, Dr RS Raju and team members for their continuous support and encouragement. Thanks are also due to DST for funding this project.

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