Thermal and Structural Analysis of Electron Gun for high efficiency Space TWT

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Abstract— **Travelling wave tubes (TWTs) are power amplifier for communication satellite. As the electron gun plays a significant role in determining the life and reliability of the space TWT, the same has been subjected for 3-dimensional thermal and structural analysis using FEA code COSMOS and ANSYS. Expansion in different electrodes like cathode, beam focus electrode (BFE) and anode in axial and radial direction has been simulated due to temperature distribution in the gun. In addition to the above, frequency analysis of electron gun assembly has also been carried out. A comparison of COSMOS and ANSYS results has been presented.**

Keywords- electron gun, space TWT, thermal analysis, structural analysis, frequency analysis.

I. Introduction

TWT is one of the most important and critical components of the satellite transponder. During operation, TWT is the hottest component of the satellite. So the thermal and structural analysis of the component of the tube is must to ensure the long life and reliability of a satellite application. Electron gun plays an important role for meeting the stringent requirement of space TWT like long life and high reliability. Life of the TWT depends upon the operating life of the cathode in electron gun. It is necessary to give due considerations in the design of electron gun from thermal and structural point of view. It is important to simulate the expansion of cathode, BFE and anode under hot condition in order to estimate radial and axial. Inter-electrode gaps [1-2]. Accordingly, margin in the respective dimensions is kept in the cold condition, so that the desired inter-electrode distances are achieved under the hot operating condition. Another important aspect of thermal and structural analysis is used for the optimum design of cathode support and heat shield to ensure minimum thermal drain from the cathode and firm holding of cathode in the electron gun.

This paper presents the thermal and structural analysis of electron gun of high efficiency space TWT. A comparison of simulated results, with respect to thermal and structural analysis including frequency analysis of the electron gun, obtained through COSMOS [3] and ANSYS [4] has been presented. Frequency analysis is important to avoid resonant vibration that can damage the gun structure. The natural frequency of the lowest mode should be greater than the specified limit (2.0 kHz).

II. Thermal And Structural Analysis Using COSMOS And Ansys: An Approch

COSMOS is a design analysis system fully integrated with SolidWorks[5]. It is based on (FEA) finite element analysis. COSMOS provides one screen solution for stress, thermal, frequency and harmonic analysis. It has post processing options to give the results as per convenience. 3-dimensional modeling of the complex geometry with asymmetric (if required) is constructed in SolidWorks and imported in COSMOS FEA analysis. This enables to analyze the actual geometry with accuracy. It has also mesh controller which enables to apply various mesh size in different zone as per requirement of level of accuracy. Range of element size can used in meshing of model with tolerance required to adjust the element size during meshing A brief process flow chart for the process used in COSMOS has been shown in Fig. 1.

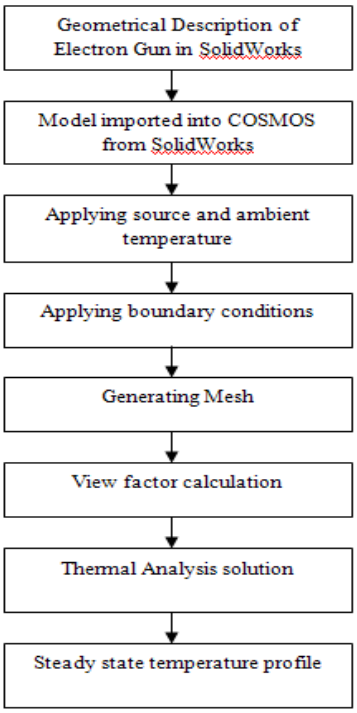

Figure 1: Flow chart of thermal analysis of electron gun using COSMOS

ANSYS finite element analysis is mostly used for thermal analysis software. It is capable of solving 2-D as well as 3-D problems. The same geometrical description of electron gun used in COSMOS FE analysis has been analyzed by the thermal point of view. Model is built and the different materials are specified. Sufficiently large numbers of nodes are generated and relatively fine meshing is accomplished. A temperature load is applied at cathode. A brief process flow chart for the computation of temperature distribution in electron gun has been shown in Fig. 2

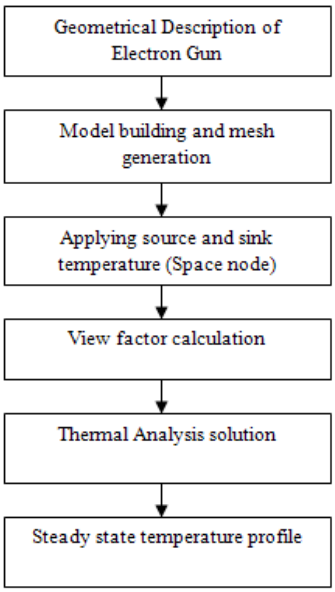

Figure 2: Flow chart of thermal analysis of electron gun using ANSYS.

III. 3-Dimanional Analysis Of Electron Gun Using Cosmos And Ansys:

As discussed in section II, axi-symmetric model of electron gun of Ku-band 140 W space TWT was made in Solid Works (Fig.3) and imported in COSMOS FE analysis (Fig. 4) from thermal and structural point of view. It is exactly the same model used in ANSYS (Fig. 5) FE analysis. The boundary conditions applied in terms of temperature (1200^0C) at heater disc under cathode construction, ambient temperature (80^0C). In ANSYS ambient temperature is used as space node temperature. In COSMOS convection coefficient (h) has also been applied for normal air cooling where value of h is 10 W/m^2-K [3], [7]. The mesh standard mesh size with incompatible interfaces, thermal resistance is 1.0e-004 m^2-K/W at braze joints and 1.42e-004 m^2-K/W [3] at TIG welding points. In ANSYS it is thermal contact conductance (TCC)[4] used instead of thermal resistance. The values of other variables like density, specific heat, thermal expansion coefficient, thermal conductivity is also the same in both codes. A steady state solution has been obtained in both the cases. A comparison of the results on the basis of temperature distribution at various electrodes and support structure, heat shield are highlighted in Table 1, which shows there is a close comparison of the temperature distribution.

As per the temperature distribution at various electrodes, an expansion in axial (Fig. 6) & radial (Fig.7) direction of cathode, BFE and anode has been obtained. The axial and radial expansion in cathode and BFE along with cathode-BFE-anode, inter-electrode axial & radial spacing obtained by COSMOS and ANSYS are highlighted in Table 2. The above estimated dimensional expansion in the hot operating condition has been observed in the cold design, so that desired inter-electrodes dimensional accuracy is obtained in hot operating condition.

It has also been observed that the agreement between the simulated results obtained from COSMOS and ANSYS FE analysis in the axial & radial deformation in cathode, BFE and anode is within 10%. In addition to above frequency analysis of the same electron gun has been carried out using COSMOS, the value of first four mode of natural frequency has been given in Table 3. The agreement within the simulated results of model frequency for COSMOS & ANSYS is 10%.

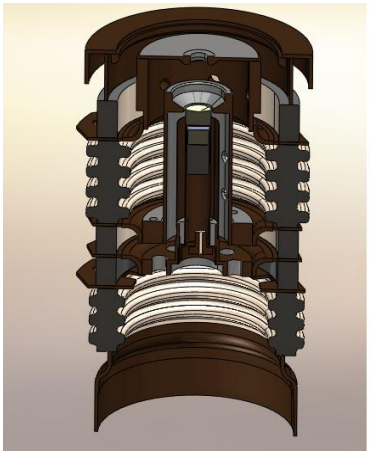

Figure 3: 3-dimensional cut view of Ku-band electron gun

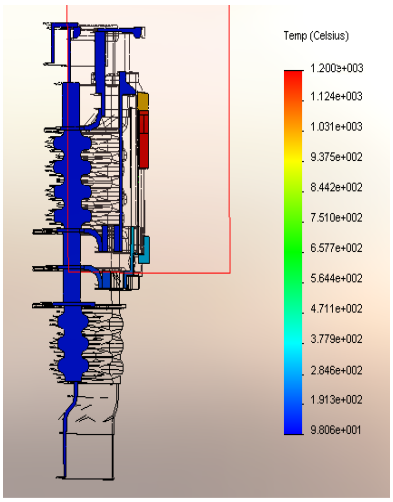

Figure 4: Temperature distribution in electron gun of Ku-band space TWT using COSMOS

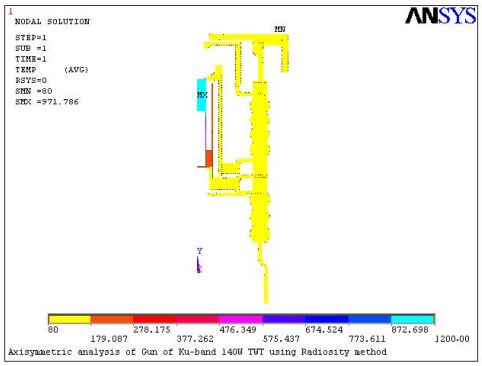

Figure 5: Temperature distribution in electron gun of Ku-band Space TWT using ANSYS

Table 1: A comparison of Temperature distribution obtained in 3-D Analysis of Electron Gun by COSMOS and ANSYS:

Location of Temperature Observation	**Temp. distribution by COSMOS**	**Temp. distribution by ANSYS**
Heater (source)	1200^{0}C	1200^{0}C
Cathode	981^{0}C	971^{0}C
BFE	123^{0}C	119^{0}C
Anode	105^{0}C	101^{0}C

Dimensional deformation in cathode and BFE in axial and radial direction computed through COSMOS has been shown in Fig.6 and Fig.7 respectively. A comparison of the dimensional changes in electrodes and cathode-BFE spacing computed from ANSYS and COSMOS are highlighted in Table 2.

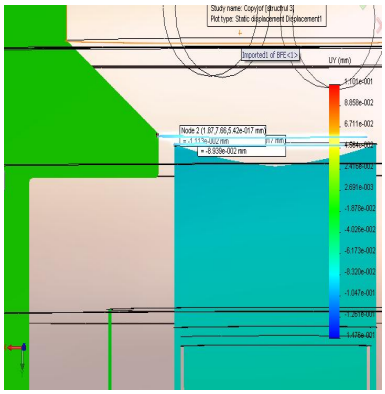

Figure 6: COSMOS model showing axial deformation

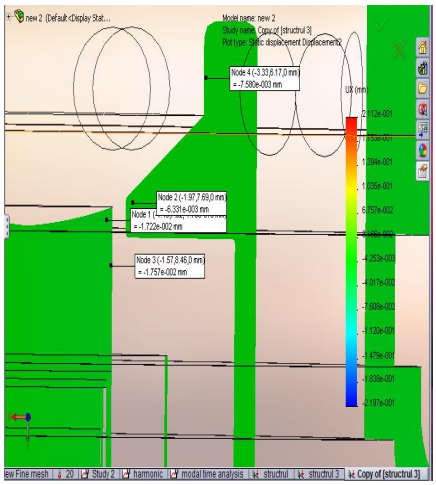

Figure 7: COSMOS model showing radial deformation

Table 2: Expansion and Inter-electrode Spacing in the operating (hot) condition of electron gun.

Electrodes		**Expansion in COSMOS (mm)**	**Expansion in ANSYS (mm)**
Cathode	[radially] Δr	0.009	0.008
	[axially] Δz	0.073	0.066
BFE	[radially] Δr	0.004	0.002
	[axially] Δz	0.011	0.012
Cathode-BFE spacing	[radially] Δr	0.244	0.24
	[axially] Δz	0.211	0.20

Table 3: Modal frequencies of electron gun from frequency analysis:

Mode	**1**	**2**	**3**	**4**
Frequency (Hz) BY COSMOS	3050	3637	6238	15057
Frequency (Hz) BY ANSYS	2933	3311	5913	14215

CONCLUSION

Thermal & structural analysis of electron gun of Ku-band 140 W space TWT has been carried out using 3-D FEA base commercial softwares COSMOS and ANSYS integrated with 3-D CAD tool Solid Works. The results of FE analysis in terms of temperature distribution and corresponding their expansion in electron gun due to same source and sink temperature and other boundary conditions along with material properties obtain for COSMOS are compared with ANSYS FE analysis. In addition to frequency analysis of the same model of electron gun has been carried out using COSMOS & ANSYS and found with 10% of agreement.

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