A Simulation Method to Determine the Assembly Distance between Cathode and Heater of Electron Gun

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Abstract: *The assembly distance between cathode and heater has significant influence on the performance of electron gun of traveling wave tubes. This paper presents a simulation method to accurately determine this assembly distance. The simulation method uses ANSYS to simulate the working state of electron gun, and transfers the thermally deformed cathode and heater models into CST through the ANSYS geometry processing module SpaceClaim. Use the contact judgment function of CST to gradually move the heater to contact the cathode to measure the distance between cathode and heater. Adjust the model on the basis of measuring results and continue simulation process until the assembly distance which satisfies the assembly tolerance rate is obtained. This method can accurately measure the distance between cathode and heater after deformation, avoid damage of electron gun under working condition and effectively guide the assembly process of electron gun.*

Keywords: thermal deformation, assembly distance, simulation, measuring distance

Introduction

The assembly error caused by thermal deformation under working conditions will seriously affect the performance of electron gun. The distance between cathode and heater is small, in the working state, contact damage may occur due to the closer distance, or heating efficiency of the heater may decrease due to the longer distance.

During fabrication, a large number of experiments are required to determine processing details. With the help of Computer Aided Engineering technology to guide processing and assembly, the resource consuming will be reduced and the development cycle will be shorten.

Prior research shows that the distance between cathode and heater after deformation is usually obtained from the analysis results and deformation trend prediction with commercial numerical simulation software, which ignores the irregular local deformation of the cathode and the heater, therefore the obtained deformation is not accurate enough.

This paper proposes a simulation method for determining the assembly distance between cathode and heater. This method performs thermal simulation of the electron gun in ANSYS Workbench to obtain the deformed structural models. Then import the deformed models into CST after being converted by SpaceClaim. In the CST, gradually move heater towards fixed cathode until they have contact to measure cathode-heater spacing in the working state. The distance measurement accuracy can be controlled within 1 μm. By this way, we can accurately get the distance between cathode and heater after deformation, effectively guide the assembly of electron gun, and prevent performance deterioration of electron gun under the working condition.

Design Methodology

The simulation method is illustrated in Fig.1. Firstly, Initialize originally designed distance between cathode and heater d_1 (accuracy of 0.01mm), the required assembly error rate E and the assembly distance between cathode and heater d_3, which is set to d_1.

Perform thermal simulation of the designed electron gun in ANSYS workbench. Convert the thermal deformed model of the cathode and the heater from STL format to SAT in SpaceClaim and import the deformed models into CST.

The distance between the thermal deformed cathode and heater d_2 is measured in CST by gradually moving the heater toward the fixed cathode until contact occurs. Calculate the assembly error rate Ea as

$$\text{Ea} = | d_1 - d_2 | / d_1 \tag{1}$$

If Ea is less than the assembly tolerance rate E, take d_3 as the final assembly distance and the simulation ends.

Otherwise update d_3 as

$$d_3 = d_3 - (d_2 - d_3) = 2d_3 - d_2 \tag{2}$$

Rebuild the model according to the updated d_3 and continue the above simulation process until the assembly error rate Ea meets the required assembly error rate E.

The detailed distance measurement process is described as follows:

(1) The moving distance d is set to the original designed distance d_1 as the initial value. If no contact occurs after moving, increase d by 0.001mm successively until contact occurs. The moving distance d before contact is the needed cathode-heater spacing d_2 and the measurement process ends;

(2) If contact occurs at the first moving step, cancel the first move. Change the moving distance d by subtracting 0.01mm and move again. Continue step (2) until no contact occurs;

(3) The moving distance d increases by 0.001mm each time until contact occurs. Record the moving distance d before contacting as d_2, and the distance measurement ends.

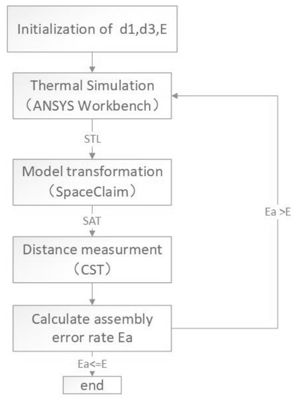


Fig. 1 Illustration of simulation process

Simulation and Results

The simulation method is demonstrated with an electron gun shown in Fig.2. The original designed distance between the cathode and the heater d_1 is 0.15mm, and the assembly tolerance rate E is 1.5%.

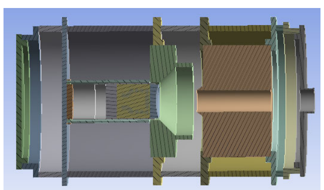
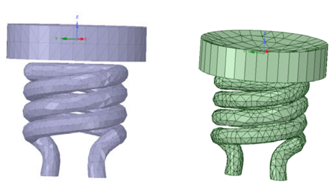


Fig. 2 Illustration of Electron gun

The thermal analysis of the electron gun is performed in ANSYS and the STL files of the deformed model of the heater and the cathode are obtained. Perform the model conversion in SpaceClaim and export the SAT files of deformed models. The deformed model and the transformed model are shown in Fig. 3.



(a) Deformed model (b) transformed model

Fig. 3 Model transformation in SpaceClaim

Import the SAT files of deformed model into CST to measure the cathode-heater spacing. Move the heater gradually towards the fixed cathode, the first moving distance d is 0.15mm. For no contact occurs, keep moving the heater by increasing d by 0.001mm successively until contact occurs. Finally, the distance between the cathode and heater d_2 is measured to be 0.162mm and the corresponding assembly error rate Ea is calculated to be 8%, which is greater than the assembly tolerance rate 1.5%. The assembly distance d_3 has to be updated as 0.138mm and the electron gun is reconstructed and the simulation process is restarted.

Once again, the distance between the cathode and the heater is measured in CST. At this time, with 0.15 mm as the initial value of d, the deformed cathode and heater is in contact. Cancel the move operation and change the moving distance d to 0.14 mm. For no contact occurs with d of 0.14mm, we. gradually move the heater towards the cathode by 0.001mm until contact occurs. Finally, we get d_2 0.148mm and Ea 1.33%, which is less than the assembly tolerance rate E of 1.5%. The corresponding d_3 here equals to 0.138 mm which is the needed assembly distance between cathode and heater.

TABLE I. process to determine Assembly Distance between the cathode and the heater

model	d_3	d_2	Ea
Original model	0.150 *mm*	0.162 *mm*	8%
Modified model	0.138 *mm*	0.148 *mm*	1.33%

TABLE I demonstrates the process to determine the assembly distance of the cathode and the heater of the simulated electron gun. It can be seen that after adjusting, the distance of 0.148 mm between the heater and the cathode is very close to the original designed distance of 0.15 mm. The assembly error rate decreased from 8% to 1.33%.

TABLE II. Effects of Assembly on Deformation and Heating Power

d_3	Cathode deformation	Heater deformation	Heating power
0.150 *mm*	0.089 *mm*	0.078 *mm*	47.926 W
0.138 *mm*	0.062 *mm*	0.055 *mm*	47.257 W

The thermal analysis of the electron gun with the optimized cathode-heater assembly spacing is also performed and the effects of assembly distance adjustment on deformation and heating power are illustrated in TABLE II. After adjusting, the deformation of the cathode and the heater have been reduced by 30.3% and 29.5% respectively. Whatsmore, when the cathode reaches the same temperature, the heating power is reduced by 1.40%, which means higher heating efficiency.

Conclusion

This paper puts forward a simulation method for determining the assembly distance between cathode and heater of the electron gun. By the process of simulation, distance measurement, model modification, the assembly distance between heater and cathode that satisfies the assembly tolerance rate will be obtained. Using this simulation method to determine the assembly distance between cathode and heater of the electron gun can effectively reduce the assembly error rate caused by thermal deformation under working conditions, improve the heating efficiency of the heater, and guide the assembly process of the electron gun.

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