Fast Optimization Design Method of Periodic Permanent Magnet Focusing System for TWT

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Abstract: *This paper proposes a fast optimization design method for the traveling wave tube (TWT) periodic permanent magnet focusing (PPM) system. Based on the target system value distribution using MTSS software, a magnetic system that satisfies the requirements is quickly designed, and the accurate single-loop value of each magnetic steel is obtained. The actual magnetic system processed according to the single-loop value is more in line with the design requirements, which is conducive to the assembly and commissioning of higher frequency millimeter wave and terahertz electric vacuum devices.*

Keywords: MTSS; TWT; PPM

Introduction

The periodic permanent magnet focusing system is an important part of the traveling wave tube, which affects the emission, focusing and collection of the electron beam. Its design directly affects the performance of the TWT.

The actual design and manufacturing process of magnetic systems is cumbersome, time-consuming, and accompanied by many uncertainties. Including: repeated magnetization and demagnetization will change the properties of the magnetic steel; imprecise manual operation when measuring the magnetic field may cause the magnetic field measurement value to deviate too much from the actual value; the misalignment of the assembly will cause the performance of the TWT; in order to correct the electronic injection, the technician will paste a lot of broken magnetic blocks around the magnetic steel. As a result, the actual magnetic field distribution is difficult to estimate.

Aiming at these problems, this paper proposes a fast optimization design method of TWT periodic permanent magnet focusing system. The MFS module in the MTSS software developed by the Academy of Computer Simulation Technology of UESTC is used to simulate and optimize the magnetic system[1]. Adjusting the magnetic system in a parameterized manner based on the target system value distribution. Firstly, adjusting the 2D calculation to obtain a magnetic field distribution that roughly meets the target value requirements. Then using local area calculations for special locations such as open magnetic steel. And then performing the overall 3D calculation to obtain a more practical magnetic field distribution. Finally, according to the structure and material parameters, getting the single-loop value of each piece of magnetic steel. And the magnetic system prepared by the technical staff according to the single-loop value is in line with the design requirements. After assembly, only simple adjustments are needed to meet the actual needs.

For higher frequency millimeter wave and terahertz electric vacuum devices, the size of the magnetic system is smaller, the electron beam channel is thinner. During the manual debugging of the device, the magnetic field on the axis changes drastically, and the electron beam may hit the high-frequency structure, which affects the performance of the TWT. Using the method in this paper, the single-loop value of each magnetic steel is obtained. The magnetic system assembled according to this only needs to be fine-tuned to maintain a stable working state, which is conducive to the development of electric vacuum devices to higher frequency bands.

Methods and Results

When using MTSS to simulate the electron gun and beam-wave interaction of the TWT[2], you can set the periodic magnetic field, and finally determine it as the target value of the magnetic system. The process of obtaining a single-loop value from the target value is shown in Figure 1.

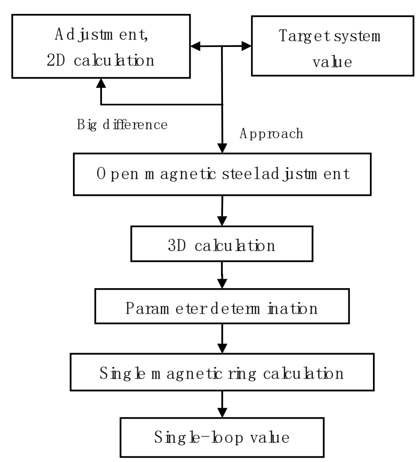

Fig. 1 The design method flow chart

Firstly establishing a magnetic system project, as shown in Figure 2. The structural parameters of the pole piece are set as variables. At the same time, the coercivity of each magnetic steel material is set as a variable. By adjusting these variables, the magnetic field distribution of the magnetic system can be easily adjusted. In this paper, we don't change the TWT structure, so the method of changing the coercivity variable is used to adjust the magnetic field.

Fig. 2 PPM system model

Due to the existence of open magnetic steel, the magnetic system model is not an axisymmetric model, and it needs to be calculated in 3D to obtain an accurate magnetic field distribution. However, adjusting the magnetic system using the overall 3D calculation method takes a lot of time.

In order to improve the efficiency, firstly adjusting the parameters repeatedly and comparing the distribution of the 2D calculation results with the target system value until the two are roughly consistent. Generally, each magnetic peak can be adjusted within 20Gs of the target system value.

Then for the open magnetic steel, adjusting the parameters and perform 3D calculation of the local area to ensure that the magnetic field distribution in the open area is consistent with the 2D results. The method is to increase the coercivity variable of the open magnetic steel to ensure that the three-dimensional calculated single-loop value of the open magnetic steel is equal to its 2D calculated single-loop value.

After that, the overall magnetic field is fine-tuned and 3D calculated. The distribution curve of the axial magnetic field Bz in the calculation results is shown in Figure 3. Each peak can be obtained by using the MTSS software post-processing tool, which should meet the target system value distribution. At this time, the structural parameters and material parameters of each magnetic steel have been determined.

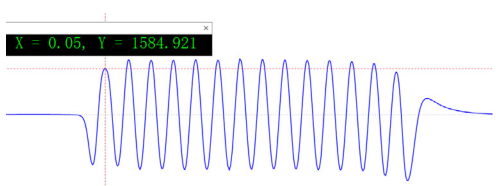

Fig. 3 Axial magnetic field distribution curve

Finally, a single-loop magnetic steel project is established, and the determined single-magnetic steel parameters are taken into account for calculation, and the single-loop value of each magnetic steel can be obtained.

Based on the information of the single-loop value, the size of the magnetic steel, and the material properties of each magnetic steel, the technician can quickly customize or process the appropriate magnetic steel. Because the entire magnetic system design process is based on the target system value, the magnetic field distribution of the magnetic system actually assembled with these magnetic steels should also meet the target. In addition, during the design of other modules such as electron guns, beam-wave interaction, and collectors, the given magnetic field requires a certain degree of redundancy in the system values, so the magnetic system assembled with the TWT only needs to be adjusted simply to ensure the electron beam is in good condition.

A set of magnetic system designed and processed using this method. The comparison between the test system value and the target system value is shown in Figure 4. Except that there are differences of about 100 Gs due to test errors in individual positions, the phase difference is generally controlled within 50 Gs, which is more in line. The upstream tube is assembled for debugging, and only a small amount of broken magnetic blocks are attached to make the test result good. The actual measurement results show that compared with the original magnetic system, the helical current of the whole pipe is reduced at multiple frequency points, the output power is increased, and the whole pipe efficiency is improved.

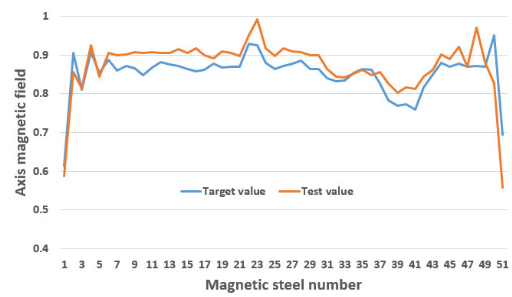

Fig. 4 Comparison of Normalized Axis Magnetic Field Amplitude

Conclusion

A fast optimization design method for the TWT PPM system proposed in this paper. Starting from the target system values, an accurate single-loop value is obtained. Compared with the traditional method, the actual magnetic system magnetic field distribution based on an accurate single-loop value is more in line with requirements and takes less time. And the test verifies the correctness and practicability of the method. And this method is also expected to have high application value in higher frequency millimeter wave and even terahertz electric vacuum devices.

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