Parametric Design and Simulation of Thermal Test Water Cooled Load Waveguides Channel

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Abstract. The purpose of this paper is to fulfill the rapid design and simulation of the thermal test water cooled load waveguides channel, according to the idea of parametric design, using the CAD software Pro/Engineer to build the model of the water cooled load waveguides channel. Calling ProToolkit function library with Visual Studio 2008 to make the program interface, it’s like a wizard to help engineers to design the thermal test water cooled load waveguides channel. It realize the thermal test water cooled load waveguides channel rapid design. With the help of software high frequency structure simulator (HFSS) and Thermal Desktop (TD), the electromagnetic and thermal performance of the thermal test water cooled load waveguides channel can be simulated. It greatly improves the efficiency of the thermal test water cooled load waveguides channel design, and guarantees the reliability of the product. The design and develop time can be reduce by 20%.

1. Introduction
Before the launch of the spacecraft, the spacecraft needs to be subjected to a thermal vacuum test to verify its on-orbit performance. During the thermal vacuum test, the spacecraft are placed in a vacuum environment simulator, it provides the vacuum cryogenic environment for the spacecraft\cite{1}. In this environment, there is no convective heat transfer, heat can only be transmitted by radiation and conduction, so some special treatment of heat dissipation is required. During the thermal test, the microwave signal generated by the specimen is absorbed by the water cooled load, and the heat is dissipated by water cooling.

It is necessary to design the water-cooled load install plate when designing the thermal test water cooled load waveguide channel. It is designed according to the actual situation such as the surface protrusion of the spacecraft, the location of the available holes. After design of the plate, it needs to assemble the water-cooled load and design the waveguide channel according to the waveguide position and the water-cooled load position. This kind of design is very regular. The rules of the water-cooled load waveguide channel can be inducted, then according the idea of parametric design, realizing the thermal test water-cooled load waveguide channel automatic design and reducing the repetitive work and improving work efficiency.

2. Parametric design
The thermal test water cooled load waveguide channel is designed by the CAD software Pro/Engineer. Pro/Engineer is a professional CAD software, widely used in the automotive, aerospace, shipbuilding and other industries. The Visual Studio 2008 C++ and Protoolkit function library were used to build the DLL files. These DLL files were used to do the data interaction with Pro/Engineer and realize the secondary development of the Pro/Engineer. This method of Pro/Engineer secondary development has
the advantages of a high execution efficiency and multiple functions achievable. This method can be used to modify the dimension of the model, assemble and create engineer drawing. A MFC DLL program can be used to create the dialog and fulfill the requirement of the parametric design.

2.1 Water cooled load channel waveguides design flow
The design flow of the thermal test water cooled load waveguide channel includes parameter setting, water cooled load install plate design and assemble, water cooled load assemble, waveguide channel design and assemble, waveguide bracket design and assemble and create engineer drawing, the design flow chart is shown in the Figure 1.

![Figure 1 Thermal test water cooled load waveguide channel design flow chart](image)

2.2 Initial parameter setting
The purpose of the initial parameter setting is to define the start and end of the waveguide path, meanwhile define the waveguide type. Firstly define the design datum by selecting the reference coordinate system and the spacecraft surface. It needs to select the spacecraft waveguide flange surface as the start position of the waveguide path. Then the position and direction of the waveguide connect surface is recorded. The function ProDimensionValueGet() is used to get the value of the size of the waveguide flange surface [2-6]. The waveguide type can be determined according to the size the waveguide flange surface. At last, it needs to select the available holes on the spacecraft surface as the install holes of water cooled load install plate, the initial state of the model is as Figure 2(a).

2.3 Design and assemble the water cooled load
Water cooled load design includes water cooled load install plate design and assemble, water cooled load assemble, heat insulation pads assemble. When design the install plate, the dimension of the install plate is defined according to the load size. The water cooled load has its specific type according
to the difference of waveguides. The waveguide type is judged by the program at the initial setting, then the install plate is designed. The center of the install plate is determined by the center of the plane consisting of several install holes which are selected during the initial setting. When the center of the plate is certain, the install plate can be designed and assembled. The install plate is 10mm from the spacecraft, engineer set the thickness of the plate, then the program using the following four functions : ProSelectionAlloc (), ProAsmcompconstraintTypeSet (), ProAsmcompconstraintAsmreferenceSet (), ProAsmcompconstraintCompreferenceSet() to assemble the install plate. After the install plate is assembled, the install holes are punched on the install plate, and the heat insulation pads between the install plate and spacecraft are assembled. The purpose of assembling the heat insulation pads is to prevent the heat transmit of the water cooled load and affecting the thermal test. At last the water cooled load is assembled, the principle of the water cooled load assembling is the water cooled load waveguide flange surface is opposite to the spacecraft waveguide flange surface. The water cooled load bracket will be modified after the waveguide is assembled.

2.4 Waveguide design
Waveguide design is includes the waveguide path design and assemble, waveguide bracket design and assemble, water cooled load bracket design and assemble. Firstly, the function ProGeomitemToSurface() is used to calculate the distance of start position of the waveguide to the spacecraft surface. If the distance is too small, then the water cooled load cannot be assembled. In that condition, the program execute waveguide start position modify algorithm and heighten the waveguide start position. When the waveguide start position is defined, the program draw a curve as the waveguide path automatically. The water cooled load waveguide flange center and the spacecraft waveguide flange center are connected by the curve. Then the specific type waveguides are load and assembled. Using the function ProDimensionValueSet() to change the waveguide dimension[2-6].

After the waveguide is assembled, then the waveguide bracket and water cooled load bracket are need to be assembled. The function ProGeomitemToSurface() is used to measure the distance from the water cooled load to the install plate, the function ProDimensionValueSet() is used to modify the dimension d1 in the Figure 2(d). The waveguide bracket design is as the same. The principle of the waveguide bracket assembly is install a bracket every 500mm, water cooled load waveguide needs a bracket. The dimension d4 in the Figure 2(c) is modified to revise the height of the waveguide bracket. At last the program punch the install holes for the water cooled load bracket and install bolts. The water cooled load channel waveguide is shown in the Figure 2(b).
2.5 Engineer drawing

The engineer drawing of the water cooled load waveguide channel include waveguide engineer drawing, waveguide bracket engineering draw, water cooled load bracket engineer drawing and water cooled load install plate engineer drawing. The water cooled load bracket engineer is taken as the example, the function ProDrawingSheetCreate() is used to create an empty engineering drawing first. Then the functions ProDrawingGeneralviewCreate() and ProDrawingProjectviewCreate() are used to create a general view and a project view. Then the function ProDimensionShow() is used to show the dimensions of the bracket according to the name of the dimensions. After that, function ProDrawingTableCreate() is used to create the table and the functions ProDwgtabledataColumnsSet(), ProDwgtabledataRowsSet(), ProDwgtabledataSizetypeSet() are used to define the sizes and number of columns and rows of the table. At last, the function ProDwgtableTextEnter() is used to fill table in the specified location of the table[2-6], the water cooled load engineer drawing is shown in the Figure 3.
Figure 3 Water cooled load engineer drawing

Figure 4 shows the human machine interface of the software. The engineer can set parameters such as datum plane, coordinate system, mounting hole and reference axis on this page. The type of waveguide and water-cooled load can be fed back on this page and can also be modified via the dropdown menu.

3. SIMULATION

3.1 Electromagnetism Simulation
After the design of the thermal test water cooled load waveguide channel, it is necessary to verify the electrical performance of the waveguide path. It is use the software HFSS to simulate the electromagnetic. An electromagnetic waveguide model needs to be created first, the waveguide path was designed by the parametric design. The HFSS model can be imported by converting the Pro/Engineer model to the stp format. This waveguide path is consist of 5 waveguides, 3 straight waveguides and 2 crooked waveguides. The material is set to vacuum, the center frequency is from 17 GHz to 19 GHz, the HFSS model is shown in the Figure 5(a), the insertion loss curve is shown in the Figure 5(b) and the Voltage standing wave radio (VSWR) curve is shown in the Figure 5(c). It can be seen in the Figure 5(b) that the maximum insertion loss is less than insertion loss. It can be seen in the Figure 5(c) that the VSWR is less than 1.06, the electrical performance of the waveguide channel is good.
3.2 Thermal Simulation

During the thermal test, the waveguides are in the vacuum cryogenic environment, there is no radiant heat source in this environment. In order to ensure that the waveguide works at the suitable temperature, it needs take some measures to control the waveguide temperature. The common measures are pasting the heat plates and covering the multilayer heat insulation component.

The software Thermal Desktop is used to do the thermal simulation. Building the thermal model with the solid brick first, setting the nodes number to 40. The material is aluminum alloy, the thermal conductivity is 237W/m·K, since the thermal model is different from the actual waveguide, so the equivalent specific heat capacity is 297J/kg·K. The absorptivity and emissivity are both 0.1. Then loading the solid heat on the three straight waveguides, the total value is 1.5W. The environment temperature is 100K. It can be seen in the Figure 6 that the waveguides temperature is between 295.5K to 304.3K. The lowest temperature is at the crooked waveguides, it satisfy the waveguide working temperature.
4. CONCLUSION
This paper achieves the purpose of the thermal test water cooled load waveguide channel rapid parameter design, it includes water cooled load install plate design, waveguide channel design, waveguide bracket design and engineer drawing. It can reduce engineer some repetitive work, improve the design efficiency and shorten the product development time. The product reliability is increased with the help of electromagnetic and thermal simulation.

This design can be improved too. For example, it is not highly automatic, so there are a lot parameters need engineer to set. With the accumulation of samples and the improvement of the algorithm, it can be more intelligent. During the simulation, the thermal and the electromagnetic model are need the engineer to redesign. It can use the secondary development method, automatic create the thermal and the electromagnetic model while designing the thermal test water cooled load waveguide channel.

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