Thermal Simulation Analysis of Reliability of an Avionics Based on Flotherm

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Abstract. Aiming at the reliability thermal design of avionics equipment, based on the reliability thermal simulation and analysis method of flotherm, the CFD digital prototype is established. The thermal simulation and thermal test of avionics equipment model are carried out at room temperature, and the results of temperature data of both are compared. The error is less than 5% to verify the correctness of the model. The thermal simulation analysis of the high temperature 70°C environment conditions is carried out by using the simulation model, and the latent heat dissipation problems and weak links of the components in the thermal design of avionics equipment are obtained. The location and cause of potential failure are pointed out to guide the thermal design of avionics equipment and improve the reliability of avionics equipment.

1. Introduction
Since the advent of integrated circuits, the integration degree of circuits has increased by several orders of magnitude. Therefore, the heat generated by each chip increases significantly, and the temperature of electronic devices increases rapidly, leading to more and more failures of electronic devices. The heat dissipation problem of integrated circuits has become the key to the miniaturization of electronic devices [1]. Therefore, in the design of avionics, in order to ensure the product quality and reliability, the structural designer should fully consider the thermal design scheme of the equipment in the development stage, and verify the correctness of the selection of heat dissipation mode and the reliability of the components by means of testing and simulation analysis.

This paper introduces a kind of Reliability thermal simulation analysis method based on flotherm certain used for certain avionics equipment, the avionics in structure thermal design considering pressure electric fan for cooling, and set the switch control of pressure electric fans start, when the environment temperature exceeds 30 °C work

Pressure electric fans. Start with appropriate Simplified principle of CFD for the setting up of avionics digital prototype, the second at room temperature (22 °C) under the condition of thermal simulation of the digital prototype and physical prototype for thermal test, according to the comparison of the temperature error is less than 5% to ensure the correctness of the simulation model, finally using the revised the avionics simulation model of high temperature 70 °C environment under the condition of thermal simulation analysis, to guide the avionics of thermal design and improve the reliability of avionics.
2. CFD Digital Prototype Modeling

2.1. Modeling
The product CFD digital prototype was obtained by importing the CAD digital prototype of an avionics device established with Creo3.0 into Flotherm 12.0, as shown in figure 1. Necessary simplification was made before importing, and the specific simplification principles are as follows [2]:

1) Remove smaller holes (such as plated through holes, etc.), raised (such as boss, etc.), rounded corners (such as chamfering, etc.);
2) Remove all connectors (screws, connectors, cables, etc.) not related to thermal analysis;
3) Keep all radiator parts.

This avionics device is mainly composed of antenna interface unit, power board, digital board, excitation module, drive and discharge module, and receive and pretreatment module. Since the components of analog circuit are high-temperature resistant devices, this paper focuses on the temperature changes of key components of digital circuit (power board and digital board).

Figure 1. A CFD digital prototype of avionics

2.2. Simulation Parameter Setting
According to the design data provided by the research unit, parameters of the following parts are set [3].

1) Box material setting
According to the material information of the box parts provided by the development unit, the material setting is carried out for all the unsimplified parts, as shown in table 1.

2) Device power setting
According to the actual power consumption of devices provided by the research unit, all devices with power consumption greater than 0.01W are modeled and set, and the remaining power is added to the circuit board in the form of power consumption of the whole board.

3) Device packaging material setting
According to the device packaging materials provided by the research unit, the corresponding packaging materials are set for all devices that need to be modeled.

4) Environmental conditioning
Set the environmental conditions of the whole machine, and set the environmental temperature according to the test profile of the product; Set the radiation of the whole machine as "sub-divided radiating", set the gravity direction to the actual gravity direction of the product.

Table 1. Table of materials corresponding to components of thermal analysis box.

| Number | Nomenclature     | Types of materials          | Mark            |
|--------|------------------|-----------------------------|-----------------|
| 1      | Cavity           | Aluminum alloy              | 5A06-H112       |
| 2      | Cover plate      | Aluminum alloy              | 5A06-H112, 5A06-O|
| 3      | Circuit board    | FR4, 4350B and Copper       | —               |
2.3. Meshing
According to the requirements of the grid division, small components set up local grid.

3. Check simulation model
Through the method of thermal test, we get under the condition of room temperature (22 °C) environmental equipment digital circuit (power supply board and digital board) the key components of the temperature test results. Compared with the simulation temperature results under the same conditions. According to the error less than 5% to ensure the accuracy of the simulation model.

3.1. Room Temperature Thermal Test
Under the condition of room temperature (22 °C) environment, the temperature below 30°C, pressure fan didn't start, avionics belongs to natural cooling. Non-contact method (PCB thermal distribution test) was used for thermal measurement test of avionics [4], Test equipment: Data acquisition system, model: omb-daq-56; Thermocouple, model: 5tc-tt-k-30-197. The measured temperature of the power board is shown in figure 2, and the measured temperature of the digital board is shown in figure 3.

![Figure 2. Measured temperature of power board at room temperature](image)

Figure 2. Measured temperature of power board at room temperature

![Figure 3. Solid drawing of digital board at room temperature](image)

Figure 3. Solid drawing of digital board at room temperature

3.2. Room temperature thermal simulation
Under the same conditions, Flotherm12.0 is used for thermal simulation of the modified simulation model. The cloud diagram of temperature distribution in thermal simulation of power supply board is shown in figure 4, and the cloud diagram of temperature distribution in thermal simulation of digital board is shown in figure 5.

![Figure 4. Room temperature simulation temperature of power board](image)

Figure 4. Room temperature simulation temperature of power board
Table 2. Comparison of test data and simulation data of main heating elements in each module

| Module name  | Device                      | Environment temperature(22°C) | Measured values°C | Simulation value°C | error% |
|--------------|-----------------------------|------------------------------|-------------------|-------------------|-------|
|              |                             |                              |                   |                   |       |
| Power strip  | RDM28S150-28JM(A1)          | 73.7                         | 74                | 0.4%              |       |
|              | RDM28S150-50JM(A2)          | 46.4                         | 48.7              | 4.9%              |       |
|              | Transformer(A4)             | 60.3                         | 59.7              | -0.16%            |       |
| Digiboard   | XC7K325T-2FFG900I(C4)       | 37.3                         | 38.7              | 3.8%              |       |
|              | LTM4644IY(C1)               | 39.4                         | 39.5              | 0.3%              |       |

3.3. Comparison of thermal simulation and thermal test results after model modification
The thermal analysis results after model modification are compared with the thermal test results, as shown in table 2. The results show that the comparison error is less than or equal to 5%.

4. Simulation at 70°C
Using the simulation model of the revised avionics equipment under the condition of high temperature (70°C) to carry out the thermal simulation analysis [5], the temperature is higher than that of 30°C, pressure fan start, through the measured wind speed of 2 m/s, belong to the air cooling heat dissipation.

4.1. Power panel thermal simulation
70°C in the simulation model is set up the environment temperature, wind speed 2 m/s boundary conditions, the power plate temperature distribution cloud image simulation is shown in figure 6, high temperature components are shown in table 3. According to GJB/components derating Z35-93 standards, digital integrated circuit components according to the class II derating, maximum junction temperature does not exceed 100°C.

Figure 5. Digital board room temperature simulation temperature

Figure 6. Power panel temperature distribution
Table 3. High temperature device in the power board

| Device | rated temperature(℃) | Junction temperature(℃) | Junction temperature(℃) | Note |
|--------|-----------------------|--------------------------|--------------------------|------|
| A1     | 125                   | 100                      | 88.1                     | Meet |
| A2     | 115                   | 100                      | 84.3                     | Meet |
| A3     | 115                   | 100                      | 88.7                     | Meet |
| A4     | 125                   | 100                      | 94.4                     | Meet |

4.2. Digital plate thermal simulation

Figure 7 shows the cloud diagram of simulated temperature distribution of digital board. See tab.4 for high-temperature devices.

![Figure 7. Digital plate temperature distribution](image)

Table 4. High temperature device in digital plate

| Device | rated temperature(℃) | Junction temperature(℃) | Junction temperature(℃) | Note |
|--------|-----------------------|--------------------------|--------------------------|------|
| C1     | 130                   | 100                      | 88.8                     | Meet |
| C2     | 100                   | 100                      | 90.4                     | Meet |
| C3     | 125                   | 100                      | 96.6                     | Meet |
| C4     | 125                   | 100                      | 92.1                     | Meet |

5. Conclusion

1. Under the condition of room temperature (22 ℃) environment thermal simulation of the digital prototype and physical prototype for thermal test, according to the comparison of the temperature error is less than 5% to ensure the correctness of the simulation model.

2. Using simulation model under the condition of high temperature (70 ℃) on the simulation analysis of the power supply board and digital board key components are lower than the temperature of the device junction temperature (℃) after consideration derating design, therefore, the key components in avionics can work reliably under high temperature conditions.

3. Verified with the method of pressure fan cooling can solve the avionics equipment under the condition of high temperature (70 ℃) heat dissipation problem.

4. Digital plate thermal design is relatively weak, hot, high, local highest temperature is 96.6 ℃, long work breakdown probability is larger, and the key of the three components on digital board temperature is higher, should give full consideration to the cooling design.

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