IIETA International Information and Engineering Technology Association
Advancing the World of Information and Engineering

International Journal of Heat and Technology
Vol. 36, No. 1, March, 2018, pp. 125-132
Journal homepage: http://iieta.org/Journals/IJHT

Thermal control design and experimental verification of light off-axis space optical remote sensor in the sun-synchronous orbit

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https://doi.org/10.18280/ijht.360117

Received: 8 August 2017
Accepted: 21 October 2017

Keywords:
sun-synchronous orbit, space optical remote sensor, thermal control design, thermal balance test.

ABSTRACT

In this study, a thermal control research is carried out for light off-axis Space optical remote sensor in the sun-synchronous orbit, and a thermal control system is designed to meet the requirements of lightweight and low power consumption. Firstly, the study analyzes the characteristics of the remote sensor, including the analysis on Space environment, the analysis on structural features of complete machine and the calculation of thermal control indexes. Secondly, based on general thought of thermal control and analysis on power consumption this study targetedly designs a thermal control system. Thirdly, this study carries out the finite element simulation and analysis for the design of thermal control in extreme low temperature and high temperature. Finally, thermal balance test is operated on remote sensor in the same working conditions. Test result indicates that: in extreme working conditions, the temperature of optical structure of remote sensor can be stable at 20±0.6℃; temperature difference in different directions is less than 1℃; the average long-term power consumption in the cycle of orbit is not more than 47.70W, which meet the thermal control indexes of complete machine and average power consumption requirement in cycle of orbit, showing that the thermal control design of the Space optical remote sensor is reasonable and feasible.

1. INTRODUCTION

Space optical remote sensor (also called Space camera) is an important means of observing the earth from upper atmosphere or out of atmosphere layer. It has been widely applied in the fields of agricultural reconnaissance, geographical mapping, marine surveillance, weather forecast and mineral reconnaissance. At present, Space camera develops rapidly in the directions of lightweight, high resolution and wide visual field. To get images with high quality, camera shall have precise direction and stable temperature. Limited by the maturity degree and reliability of platform, Space camera needs to strictly adapt to the constraint conditions of satellite platform while meeting its own development demand. Furthermore, it will need to meet the requirements of lightweight, low power consumption, environmental adaptability and long lifetime. Thermal control subsystem is facing more and more challenges and difficulties as the environment security system of Space camera.

Design of the thermal control system of Space optical remote sensor is closely related to Space environment, speed of response, structural features and energy distribution. Different Space environment of different orbits of remote sensor (such as Lagrangian point [1-2], Geostationary Earth Orbit [3-4], sun-synchronous orbit [5] etc.) may lead to prominently different thermal control designs. Rapid adaptability, deployment ability, flexibility of design required by rapid response sensor [6-7] bring corresponding challenge to design of thermal control. Type of optical system (coaxial and off-axis design) of remote sensor, compactness of structure and layout characteristics can directly influence design of thermal control. External thermal flow and internal thermal source of remote sensor shall be considered in thermal control design. Different thermal control system of optical remote sensor of different type has different characteristics. On the whole, passive thermal control and active thermal control are combined in thermal control design of Space remote sensor. Passive thermal control design is the preferred scheme. Strictly limited by resource and power consumption, overall-passive thermal control design is used for some remote sensors. As for development of domestic and foreign thermal control, foreign research on thermal control as necessary security technology [8-11] is earlier because development of foreign Space remote sensor is started earlier. In the latest years, domestic development of Space sensor is rapid. Some types have reached world advanced level; achievements have been got in corresponding thermal control research [12-15].

Light off-axis Space optical remote sensor of certain type moves in the sun-synchronous orbit. It especially requires lightweight and low power consumption. Principal part of remote sensor strictly requires stability of temperature and temperature difference and strictly limits long-term power consumption of thermal control. Deep research is needed for the method of meeting index requirements and lowering power consumption. A suitable thermal control system is designed aiming at the optical remote sensor in this paper. Besides, simulated analysis and test verification are done to guarantee a reasonable and feasible thermal control design.

2. ANALYSIS ON CHARACTERISTICS OF CAMERA

2.1 Analysis on space environment

The light off-axis Space camera researched in this paper moves in the typical sun-synchronous orbit, such as the orbit of meteorological satellite, resource satellite and remote sensing satellite. The orbit parameters of satellite are listed in Table 1.

Table 1. Orbit parameters of satellite

No.	Type of orbit	Synchronous circular orbit of sun
1	Height of orbit	650km
2	Inclination of orbit	98°
3	Local time of descending node	10:30am

The Space external thermal flow in orbit mainly comes from direct solar radiation, infrared radiation of earth and earth albedo. The Space external thermal flow reaching camera is relevant to position of camera at different time and its direction relative to the sun and earth.

In four seasons of year, the angle between sunlight and satellite orbit plane (namely angle β) always changes. Solar constant, albedo angle of earth and infrared heat flow of earth fluctuate in certain range. Above factors can directly influence the external heat flow of camera. In theory, above influencing factors have infinite combinations. In thermal analysis and thermal test, the lowest external heat flow and the highest external heat flow are usually chosen. Thermal design of the complete machine can be sufficiently assessed.

The change of angle β of the camera in working orbit is shown in Figure 1. The high-temperature working condition and low-temperature working condition of the camera in orbit are defined in Table 2.

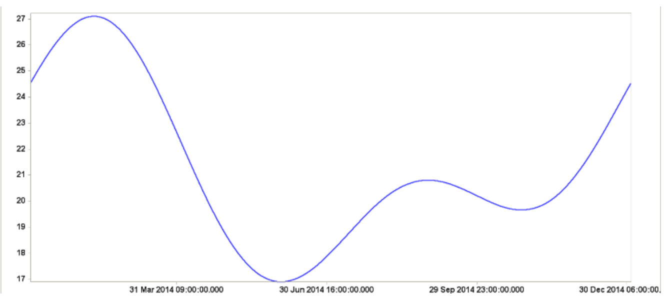


Figure 1. The curve of angle β change in life cycle

Table 2. The high-temperature and low-temperature working condition of the camera in orbit

Parameters	High-temperature working condition	Low-temperature working condition
Absolute value of angle β	27.1° (Feb.9)	16.9° (Jun.2)
Solar constant (W/m^2)	1414	1322
Infrared radiation of earth (W/m^2)	235	230
Earth albedo	0.35	0.30
In-orbit phase	The last phase of life cycle	The first phase of life cycle

2.2 Characters of complete machine

The camera has off-axis three-reflector optical system without central obstruction. The optical system contains three aspherical mirrors: the first reflector, the second reflector and the third reflector. To make structure of the optical system compact, a plane reflector (focusing mirror) is added between image plane and the third reflector to play the function of folding light path.

The main supporting structure of the camera is a framework structure. Four groups of reflector module are respectively installed on 2 groups of framework. The first reflector and third reflector are installed on back framework; the second reflector and focusing mirror are installed on the front framework. Diaphragm is set between frameworks and thin-gauge skin is covered on the frameworks. 4 installation supports are used for the mechanical connection between the camera and satellite platform. Structure of the camera is shown in Figure 2.

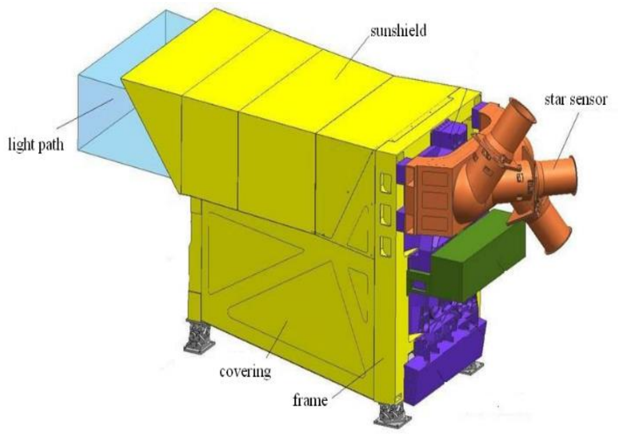


Figure 2. Structure of the camera

2.3 Determination of thermal control indexes

Fundamental objective of Space thermal control system of camera is to guarantee the optical performance of camera and imaging quality of camera. The following methods can be used to determine thermal control indexes of the system:

(a) Analogy analysis method: Up to now, there have been lots of experience and achievements in research and development of Space optical remote sensor at home and abroad. Summarize the Space environment, optical system, structural form and task demand of the movement in orbit, explore universality and comparability and determine thermal control indexes based on the successful cases in previous types.

(b) Physical characteristics method: for example, as for electronic components, temperature can significantly influence work performance, reliability, failure rate, dark current and noise. Corresponding thermal control indexes can be determined considering demand of physical characteristics and limitation of environmental conditions.

(c) Thermal optical analysis method: based on optic-mechanical thermal joint simulation and performance indexes of complete machine, permissible deviation and boundary of temperature of camera can be explored.

Up to now, lots of research findings have been got in thermal optical analysis on Space camera. Firstly, build finite element model of thermal analysis aiming at screen samples, make thermal analysis on complete machine to get temperature distribution, map temperature field on the finite element model of complete machine for thermos-elastic analysis, get rigid body displacement and corner angle information of reflector module, fit deformation of mirror plane based on discrete data, input the deformation information into optical design software for optical performance analysis (modulation transfer function MTF, usually) and determine temperature adaptability by iterative inversion. Optic-mechanical thermal integrated analysis flow [16] is shown in Figure 3.

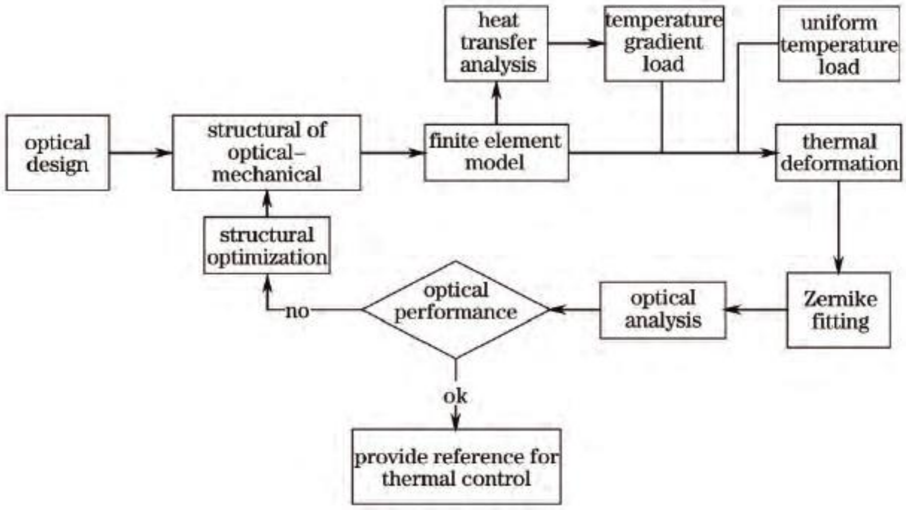


Figure 3. Optic-mechanical thermal integrated analysis flow

Based on PV value, RMS value, rigid body displacement and corner angle in thermal optical analysis, judging by the second reflector with the highest temperature sensitivity, the rigorous temperature range of complete machine is 20±2.3℃. Because of the large difference of temperature adaptation of different parts and modules of complete machine, thermal optical analysis result is combined with analogy analysis and physical characteristics method. In addition, overdesign principle is considered to determine the thermal control indexes of complete machine in Table 3.

Table 3. Thermal control indexes of complete machine

No.	Thermal control indexes	Value / °C
1	Temperature level of optical mechanism	20±1.5
2	Temperature difference of optical mechanism in X, Y and Z directions	≤2
3	Temperature difference of lens hood	17~23

3. THERMAL CONTROL DESIGN

3.1 General thought

Based on input conditions of thermal design and thermal control indexes, the general thought of thermal control is specified below:

1) Several layers of thermal insulation are used to cover the complete machine to insulate internal thermal environment from external thermal environment of the camera and decrease the interference of change of external heat flow to the stability of temperature of the camera.

2) Thermal insulation shall be designed between the camera and the support base of satellite. Several layers of thermal insulation are used to cover the relative side between the camera and satellite to avoid the temperature fluctuation of satellite platform influencing temperature level of the camera.

3) Black paint that absorbs light is sprayed on the internal of camera to enhance internal radiation heat exchange.

4) Actively control optical mechanism of the camera to guarantee reasonable range of temperature level of optical mechanism and internal temperature difference.

5) Actively control the thin-gauge skin and lens hood of the camera to guarantee internal temperature environment of the camera.

6) Several layers of thermal insulation are used to cover certain internal area of the camera to significantly decrease the heat leakage influence of optical aperture.

3.2 Analysis on power consumption

The balance temperature of the camera in orbit is based on law of conservation of energy. Thermal balance relation of the camera is:

$$Q_1 + Q_2 + Q_3 + Q_4 + Q_5 + Q_6 = Q_7 + Q_8 \tag{1}$$

where, $Q_1 = \sum_{i=1}^{n} (A_i \alpha_s S \varphi_{1i})$, Q_1 is the heat flow of direct radiation of sun; A_i is the area of the i^{th} surface; α_s is the surface sun absorption rate; S is radiation constant of sun; φ_{1i} is radiation angle coefficient of sun of the i^{th} surface.

$Q_2 = \sum_{i=1}^{n} (A_i S a \varphi_{2i})$, Q_2 is the reflected heat flow of the earth; a is average reflection rate of the earth; φ_{2i} is reflection angle of the earth coefficient of the i^{th} surface.

$Q_3 = \sum_{i=1}^{n} (A_i \frac{1-a}{4} S \varphi_{3i})$, Q_3 is infrared heat flow of the earth; φ_{3i} is infrared angle coefficient of the earth of the i^{th} surface.

Q_4 is background radiation heat flow of universe; Q_5 is internal heat source of the camera; Q_6 is compensatory power consumption of active thermal control of the camera.

$Q_7 = \sum_{i=1}^{n}(\varepsilon_i A_i \sigma T_i^4)$ is heat dissipating capacity of the camera; Q_8 is change of internal energy of the camera.

Optical entrance of the camera is A_1, the compensatory power consumption of active thermal control is:

$$Q_6 = \underbrace{(\varepsilon_1 A_1 \sigma T_1^4 - A_1 \alpha_s S \varphi_{11} - A_1 S a \varphi_{21} - A_1 \frac{1-a}{4} S \varphi_{31})}_{K_1} + \underbrace{\left[\sum_{i=2}^{n}(\varepsilon_i A_i \sigma T_i^4) - \sum_{i=2}^{n}(A_i \alpha_s S \varphi_{1i}) - \sum_{i=2}^{n}(A_i S a \varphi_{2i}) - \sum_{i=2}^{n}(A_i \frac{1-a}{4} S \varphi_{3i})\right]}_{K_2} + Q_8 - Q_4 - Q_5 \quad (2)$$

When stable thermal balance of the cameral is reached in orbit, Q_8=0. Background radiation Q_4 of universe can be ignored. Internal heat source of the camera is embedded in the camera. It is not involved in the calculation of heat exchange of the camera. K_2 is the heat exchange quantity of the camera except for its optical hole. As for the surface covered with several layers of insulation, the value of K_2 is 4W/m^2~8W/m^2. Using the middle value 6W/m^2, envelope size of the camera is the external envelope size of the complete camera: 1049mm×803mm×1331mm (X direction × Y direction × Z direction). The total area is 6.61m^2; quantity of heat leakage is about 39.7W. In 650km sun-synchronous orbit, average value of the latter three of K_1 is 295W/m^2; the size of optical aperture is about 753mm×453mm. Equivalent temperature of optical aperture is 20℃. Equivalent emissivity is ε=0.9.

Quantity of heat leakage of optical aperture K^1 is about 27.7W; Q_6 is 74.1W. The quantity of heat leakage of optical aperture is much larger than that of any surface of camera. It is equivalent to 70% total heat leakage of other surfaces. If the limitation condition of low power consumption shall be met, it is the effective measure of lowering equivalent temperature of optical aperture for decreasing quantity of heat leakage. When equivalent temperature of optical aperture lowers to10°C and heat leakage K_1 lowers to 11W, Q6 can lower to 50.7W. Therefore, the thermal control design at optical aperture shall be especially considered.

3.3 Thermal control design

Thermal control scheme can be designed based on above analyses. The thermal control measures are listed below:

1) 15 units of several-layer thermal insulation are used to cover the external surface of the camera. Every unit is comprised of 1 layer of double-side aluminizing polyester film with thickness 6μm and 1 layer of dacron net. A layer of F46 secondary surface-mirror film is used to cover the external surface of several-layer thermal insulation. Double-side aluminizing polyester film with thickness 25μm is used for the internal surface of several-layer thermal insulation.

2) Lens hood has direct mechanical connection with +Z side of framework of camera. To avoid deformation of framework caused by temperature difference, 10 units of several-layer thermal insulation material are used to cover internal surface of lens hood and the framework close to optical aperture. Special black silk cloth with low reflectivity (lower than 4%) is selected for facial mask. Other several-layer modules accord with several-layer insulation out of the camera.

3) The camera has mechanical connection with satellite platform by 4 support bases. 4 Φ8 screws are set for each base. Polyimide heat insulation pad with thickness 8.5mm is set for the junction surface between satellite platform and each support base.

4) ERB-2B black paint is sprayed on the internal surface of the camera to enhance internal radiation heat exchange, homogenize temperature of camera and restrain stray light. Infrared emissivity ε≥0.9.

5) To maintain the temperature level of the camera, active temperature compensation is given to parts of the camera. 16 heating areas are set in total. Each heating area involves double temperature control loops. General temperature control loop of the camera involves 16 loops of main backup. Heating component is 125-type electric heater. Temperature measurer is MF61 thermistor. Adhesive is GD414C silicone rubber.

6) In regular working status, main temperature control loop works; cold backup of heater band and thermal backup of thermistor are in backup temperature control loop.

The active thermal control heating area of camera is in table 4. Designed power in the table is the heating capacity of single heating loop. The statistical method of average power consumption in orbit cycle: designed power × (heating time in orbit cycle / the length of orbit cycle). The sum of average power consumption in orbit cycle of all heating areas is the long-term energy consumption of complete machine.

Table 4. Distribution of heating areas of active thermal control

No.	Code of heating area	Name of heating area	Designed power (W)	Code of temperature control point
1	H1A/B	The 1st reflector	3.9	T1A/B
2	H2A/B	The 2nd reflector	1	T2A/B
3	H3A/B	The 3rd reflector	2.3	T3A/B
4	H4A/B	The 4th reflector	3	T4A/B
5	H5A/B	Front framework	6.3	T5A/B
6	H6A/B	Area 1 of middle framework	9.1	T6A/B
7	H7A/B	Area 2 of middle framework	3.9	T7A/B
8	H8A/B	Area 3 of middle framework	9.8	T8A/B
9	H9A/B	Area 4 of middle framework	5.3	T9A/B
10	H10A/B	Area 1 of back framework	6.6	T10A/B

11	H11A/B	Area 2 of back framework	7.1	T11A/B
12	H12A/B	Area 1 of lens hood	0.2	T12A/B
13	H13A/B	Area 2 of lens hood	4.1	T13A/B
14	H14A/B	Area 3 of lens hood	3.1	T14A/B
15	H15A/B	Area 4 of lens hood	0.4	T15A/B
16	H16A/B	Area 5 of lens hood	0.6	T16A/B

4. THERMAL ANALYSIS

4.1 Modeling for thermal analysis

The thermal module of Space system in Siemens NX is used for thermal analysis and calculation, including preprocessing, solution and postprocessing. To improve quality of grids of finite element, lower solution difficulty and decrease calculation time, the structure models input shall be reasonably deleted and simplified, namely so-called "idealization". According to the structure design of complete machine and actual need of thermal analysis, the following ideal operations are completed for structure of camera:

1) Eliminate the screw holes and chamfers in structural components and the geometrical characteristics not concerned in thermal analysis.

2) Delete standard structural components of screws, nuts and spacers; its influence on heat conduction is reflected in the value assignment of thermal contact resistance.

3) "Middle plane" is extracted for geometrical characteristic of thin plate for replacing solid modeling with "middle plane" modelling.

Based on the structural features of the camera and the need of thermal analysis, finite element model is built for complete camera. Schematic diagram of finite element model is in Figure 4.

Thermal coupling is endowed to all joint surfaces of the camera to simulate the process of heat conduction, including glue joint and mechanical joint. The definition of thermal contact conductivity of joint surfaces are defined in table 5. The attributes of materials are listed in Table 6.

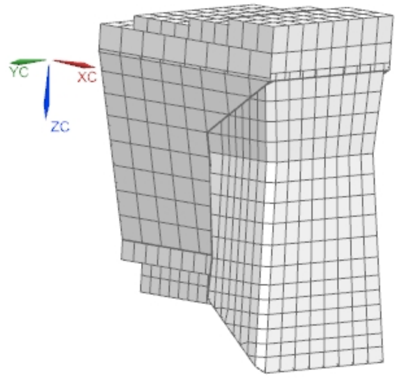


Figure 4. Finite element model of complete machine

Table 5. The definition of thermal contact conductivity

Type of contact	Thermal control technology	Thermal contact conductivity W/(m²·K)
Non-metal surface-metal surface	-	100
Non-metal surface-metal surface	Glue joint	300
Non-metal surface-metal surface	Insulated heat conduction pad	150
Metal surface-metal surface	-	200
Metal surface-metal surface	Fill heat-conducting glue	500
Metal surface-metal surface	Fill heat conduction grease	1000
Between internal surface and external surface of several-layer thermal insulation module	-	0.05 (Equivalent)

Table 6. Definition of attribute of materials of camera

Material	Density kg/m³	Thermal conductivity W/(m·K)	Thermal capacity J/(kg·K)	Emissivity ε	Sun absorptivity α
Silicon carbide	3200	160	675	0.7	-
Surface of reflector	-	-	-	0.05	-
Silica glass	2200	1.38	733	0.5	-
Titanium alloy	4440	5.44	650	-	-
Aluminum matrix composite	2900	235	900	0.6	-
Invar	8100	13.9	1647.8	0.6	-
Carbon fiber	1600	25	600	0.75	-
REB-2B black paint	-	-	-	0.90	-
F46 film (initial phase of lifetime)	-	-	-	0.65	0.15
F46 film (last phase of lifetime)	-	-	-	0.65	0.35
Polyimide	1400	0.37	1100	-	-

4.2 Thermal analysis on working conditions and results

Thermal analysis is made on low-temperature working conditions and high-temperature working conditions. Working conditions are specified below:

1) Low-temperature working conditions: reasonable combination of minimum external heat flow, minimum internal thermal consumption, lowest temperature boundary, features of thermal control materials in initial phase of lifetime, shade of the earth etc.

2) High-temperature working conditions: reasonable combination of maximum external heat flow, maximum internal thermal consumption, highest temperature boundary, features of thermal control materials in last phase etc. in orbit of satellite.

Temperature of the camera and task satisfaction degree in thermal analysis on working conditions in low temperature are shown in Table 7.

Temperature of the camera and task satisfaction degree in thermal analysis on working conditions in high temperature are shown in Table 8.

Table 7. Temperature and task satisfaction degree in thermal analysis on working conditions in low temperature

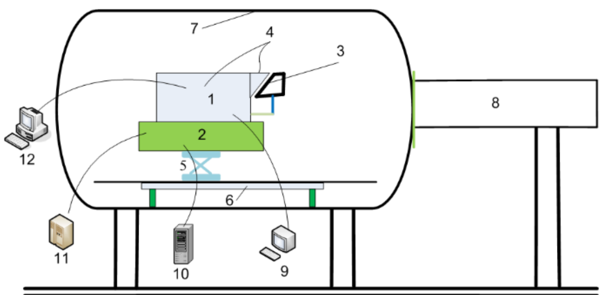
No.	Indexes of thermal control	Value / °C	Calculation result / °C	Satisfaction degree
1	Temperature of optical mechanism	20±1.5	19.3~20.6	Satisfied
2	Temperature difference in X direction, Y direction and Z direction of optical mechanism	≤2	≤1.3	Satisfied
3	Temperature of lens hood	17~23	18.1~20.9	Satisfied

Table 8. Temperature and task satisfaction degree in thermal analysis on working conditions in high temperature

No.	Indexes of thermal control	Value / °C	Calculation result / °C	Satisfaction degree
1	Temperature of optical mechanism	20±1.5	19.9~20.9	Satisfied
2	Temperature difference in X direction, Y direction and Z direction of optical mechanism	≤2	≤1.0	Satisfied
3	Temperature of lens hood	17~23	18.4~21.2	Satisfied

5. TEST VERIFICATION OF THERMAL BALANCE

5.1 Test plan



Note: 1. Space optical remote sensor; 2. Simulated fixture of satellite platform; 3. Infrared heating cage; 4. Absorption of external heat flow; 5. Adjustment platform; 6. Objective table; 7. Space environment simulator; 8. Parallel light pipes; 9. Active thermal control management unit; 10. Program-control temperature control system with power source; 11. Program-control heating system with power source; 12. KEITHLEY temperature measurement system

Figure 5. Test system

Thermal balance test on complete machine is operated to verify the correctness and rationalization of thermal control design. The test system includes Space optical remote sensor after thermal implementation, Space environment simulator, external heat flow modules, infrared heating cage, simulated module of internal heat source, simulated module of satellite platform, temperature measurement module, program-control heating system with power source, program-control temperature control system with power source, active thermal control management unit, KEITHLEY temperature measurement system, matched fixtures and cables. The structure of test system is shown in Figure 5.

5.2 Temperature judgment points of thermal balance and the criterion of judgment

Temperature judgment points of thermal balance are the temperature control points of optical mechanism of the camera. The actual temperature judgment points are listed in Table 9. As for stable working conditions, the temperature fluctuation value shall not be more than ±0.5℃ in continuous 4h at temperature point, or the monotonic change of temperature in continuous 4h is not more than 0.1℃/h. In this case, it is thought the camera reaches the state of thermal balance.

Table 9. Temperature judgment points for thermal balance

No.	Code of heating area	Position of temperature control points	Code of temperature control points
1	H1A/B	The 1st reflector	T1A/B
2	H2A/B	The 2nd reflector	T2A/B
3	H3A/B	The 3rd reflector	T3A/B
4	H4A/B	The 4th reflector	T4A/B
5	H5A/B	Front framework	T5A/B
6	H6A/B	Area 1 of middle framework	T6A/B
7	H7A/B	Area 2 of middle framework	T7A/B
8	H8A/B	Area 3 of middle framework	T8A/B
9	H9A/B	Area 4 of middle framework	T9A/B
10	H10A/B	Area 1 of back framework	T10A/B
11	H11A/B	Area 2 of back framework	T11A/B

5.3 Result of thermal test

According to the criteria of judging thermal balance in stable working condition, the temperature change in thermal balance phase in low temperature is shown in Figures 6 and 7.

The thermal control indexes in the working condition of low temperature of the camera and the degree of satisfaction of design restraint are shown in Table 10: test result of working condition of low temperature of the camera meets the requirement on thermal control indexes and design restraint.

The temperature change in balanced phase in high-temperature working condition of the camera is shown in Figures 8 and 9.

The thermal control indexes of the camera in high-temperature working condition and degree of satisfaction of design restraint are shown in Table 11: test result of working condition of high temperature of the camera meets the requirement on thermal control indexes and design restraint.

In test result, the thermal control design of remote sensor meets indexes of thermal control and the requirement on average power consumption in orbit cycle. In addition, result of thermal analysis and result of thermal test can be well identical. In addition, estimated value of average power consumption in orbit cycle of active thermal control can be well identical with statistical value in test.

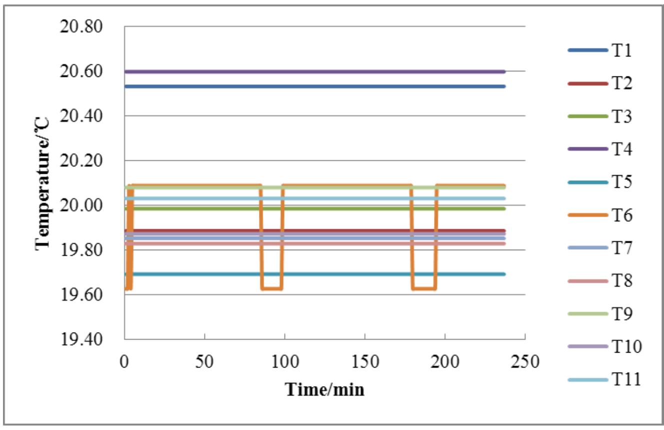


Figure 6. Temperature of optical mechanism of the camera in the working condition of low temperature

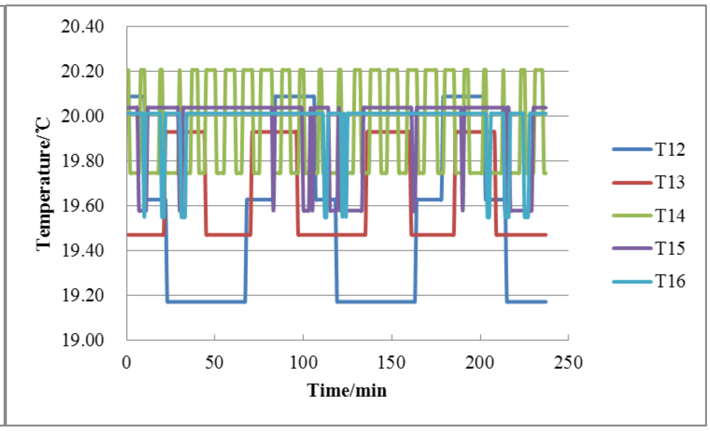


Figure 7. Temperature of lens hood of the camera in the working condition of low temperature

Table 10. The thermal control indexes in the working condition of low temperature of the camera and the degree of satisfaction of design restraint

Thermal control indexes	Value (°C)	Test result (°C)	Degree of satisfaction
Temperature of optical mechanism	20±1.5	19.63~20.60	Satisfied
Temperature difference in X direction, Y direction and Z direction of optical mechanism	≤2	≤0.97	Satisfied
Temperature of lens hood	17~23	19.18~20.21	Satisfied
Average power consumption in orbit cycle	≤50W	47.70W	Satisfied

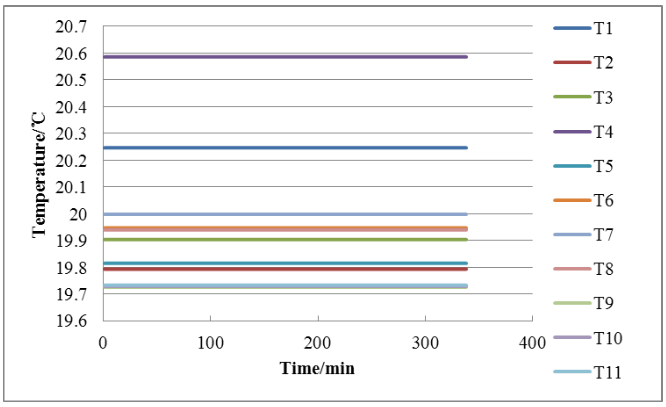


Figure 8. Temperature of optical mechanism of the camera in high-temperature working condition

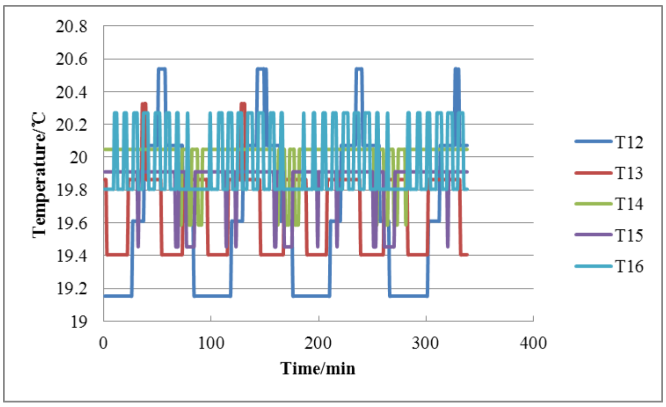


Figure 9. Temperature of lens hood of the camera in high-temperature working condition

Table 11. The thermal control indexes of the camera in high-temperature working condition and degree of satisfaction of design restraint are shown

Thermal control indexes	Value (°C)	Test result (°C)	Degree of satisfaction
Temperature of optical mechanism	20±1.5	19.62~20.57	Satisfied
Temperature difference in X direction, Y direction and Z direction of optical mechanism	≤2	0.95	Satisfied
Temperature of lens hood	17~23	19.15~20.54	Satisfied
Average power consumption in orbit cycle	≤50W	36.24W	Satisfied

6. CONCLUSIONS

Targeting certain light off-axis Space optical remote sensor as the objective of research, this paper analyzes Space environment of remote sensor in orbit, clearly specifies structural features of the complete machine, calculates thermal control indexes of remote sensor, estimates average long-term power consumption in orbit cycle of thermal control considering the demand of lightweight and low power consumption of the remote sensor, completes targeted thermal control design and verifies the thermal control design by thermal analysis and thermal balance test. In the test result, in extreme working conditions, the temperature of optical mechanism of the remote sensor can be stable at 20±0.6°C; temperature difference in different directions is less than 1°C; average long-term power consumption in orbit cycle is not more than 47.70W, meeting thermal control indexes and the requirement on average power consumption in orbit cycle of thermal control. The thermal control design is reasonable and feasible. Research achievements in this paper can offer references and bases for the thermal control design of other optical sensors in the sun-synchronous orbit.

ACKNOWLEDGMENT

This research was supported by a National Natural Science Foundation of China project, which is a part of an innovation project. All the experiments were carried out in the space test hall of the Changchun Institute of Optics, Fine mechanics and Physics, Chinese Academy of Sciences.

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