Analysis of the influences of view angle on paraboloid W style radiant cooler's working performance

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In this paper, the performance of a paraboloid W style radiant cooler was numerically simulated under different view angles. By analyzing the data of calculating results, it is found that the temperature of cold stage declined linearly when the view angle decreased, while the fabrication and the inner heat-exchange of radiant cooler are very complicated. Furthermore, the negative affects can be reduced by changing the temperature-controlling mode of ambient housing.

INTRODUCTION

Radiant cooler is one of the cooling methods for the infrared remote sensing systems on spacecrafts. It has advantages of no vibration, no noise, only a very little power consumption, and high reliability, etc. As a passive cooling device, the cooling capacity of radiant cooler is small and the requirements to spacecraft orbit and mounted position are strict [1]. This limited the applications of the radiant cooler. So the study of factors influencing working performance of radiant cooler has become hot spot in radiant cooler research fields.

When a radiant cooler was designed, following considerations should be taken into account: 1) enlarging the view angle of patch to cold space, 2) shielding most input of the external heat flux, 3) decreasing the leakage of thermal flow between different stages [2]. However, in most cases the view angle of radiant coolers applied in spacecrafts can't reach the perfect maximum because of the limitation of spacecraft structure, satellite orbit, and the mounted position. In this paper, the view angle influencing on the cooler performance has been numerically studied.

MODE AND METHODS OF CALCULATION

The paraboloid W style radiant cooler is selected as the calculation mode in this paper. Figure 1 is the physical mode of this radiant cooler [3]. Figure 2 shows two schemes of cold patch and first stage radiator when the horizontal view angle was decreased. In the scheme that the first stage radiator is folded the angle of γ, the areas of first stage radiator and cold patch are bigger. For the reason that the area is very important to the working performance of radiant cooler, this scheme is selected to satisfy the varied view angle in paraboloid W style radiant cooler.

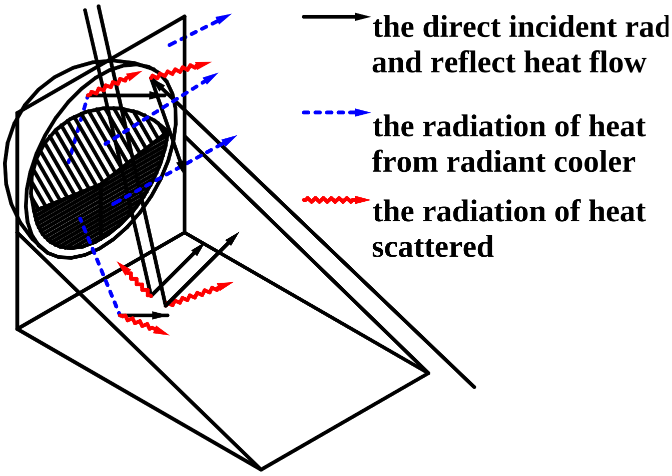

Figure 1 Thermal physical mode of paraboloid W style radiant cooler

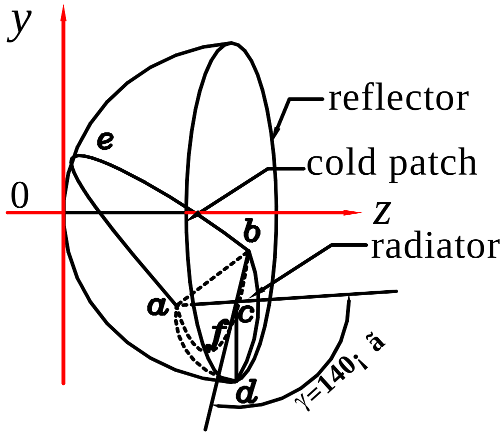

Figure 2 Scheme of radiator and cold patch

Based on the thermal physical mode and analysis of the input of external thermal flow, the thermal balance equations for the ambient housing, the first stage, and the second stage were respectively formulated.

By analyzing these thermal balance equations, the fact that only $E_{d\text{-}sho}$, $E_{p\text{-}co}$, A_d, A_p, $E_{d\text{-}sh}$, and $E_{p\text{-}c}$ change with the view angle was found, $E_{d\text{-}sho}$: exchange factor between first stage and open mouth of shield, $E_{p\text{-}co}$: exchange factor between patch and open mouth of cone, A_d: area of first stage, A_p: area of patch, $E_{d\text{-}sh}$: exchange factor between first stage and shield, $E_{p\text{-}c}$: exchange factor between patch and cone.

The calculated results of A_p and A_d are listed in Table 1.

Table 1 Value of A_p and A_d to different horizontal view angle

Horizontal view angle γ	180°	170°	160°	150°	140°
A_p（cm^2）	476.5	437.2	400.1	365.9	335.9
A_d（cm^2）	722.8	691.8	665.4	641.9	621.7

Because the inner heat-exchange system of radiant cooler includes paraboloid revolution surface, the exchange factor can not calculated by a simple function. The theoretic calculation is carried out by the Monte Carlo method. The Monte Carlo method is a numerical method based on the statistical principle, and has been widely used in many research fields.

ANALYSIS OF CALCULATED RESULTS

The working performance of radiant cooler was calculated in two different conditions. One status is the temperature of ambient housing is controlled together with the infrared detecting system. In this case, the temperature of ambient housing is 292 K. Another status is the temperature of ambient housing is controlled separately and the temperature of ambient housing is 270 K. There are three kinds of heat load loaded on cold patch. They are no loads, 60 mW and 100 mW.

The numerical calculation of working performance of paraboloid W style radiant cooler was carried out and several curves were plotted according to the calculated results.

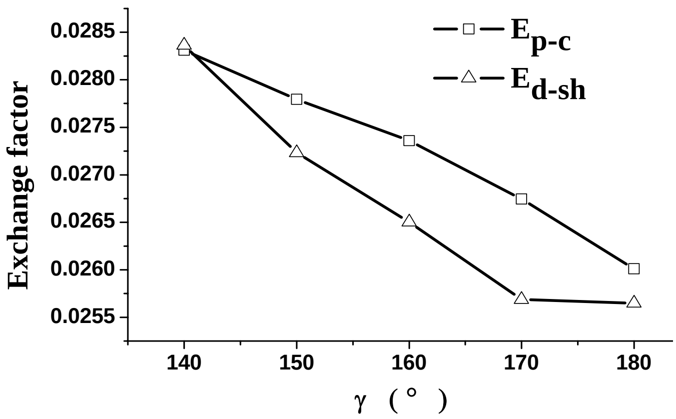

Figure 3 Exchange factors among surfaces dependence on view angle

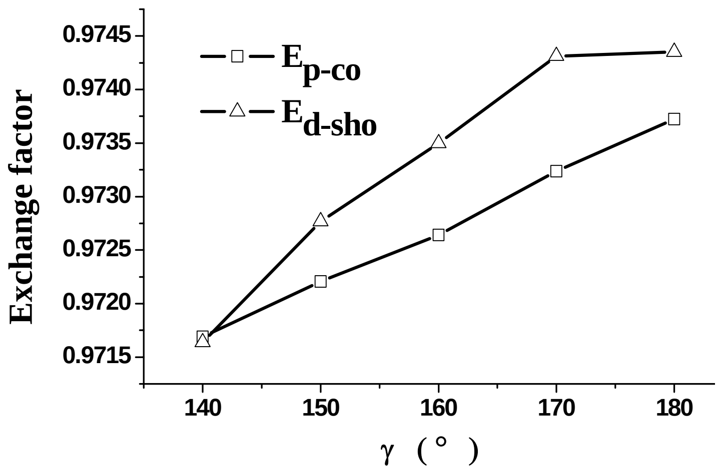

Figure 4 Exchange factors to cold space dependence on view angle

The curves of exchange factors changing with view angle are showed in Fig 3 and Fig 4. $E_{d\text{-}sh}$ and $E_{d\text{-}sho}$ change remarkably because not only the area of first stage radiator is decreased, but also the position to the shield of earth changes simultaneously, when the horizontal view angle γ varies from 180° to 140°.

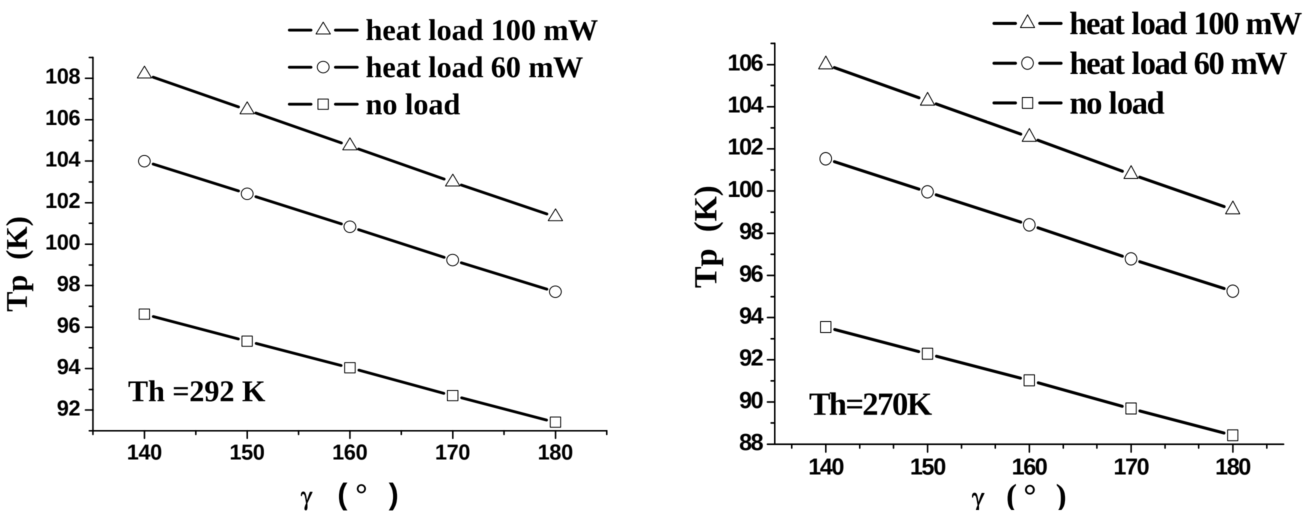

Figure 5 Temperature of second stage dependence on view angle

Figures 5 show that the temperature of second stage T_p change linearly with the horizontal view angle γ. For every 10° γ decrease, T_p increased by1.27 K with no loads, by1.57 K with 60 mW heat load, and by 1.72 K with 100 mW heat load. The heat load of cold patch also influences the sensitivity of second stage temperature changing with the view angle. According to the calculated results, when the horizontal view angle γ varies from 180° to 140° and the temperature of ambient housing is controlled at 270 K, the temperature of second stage T_p increases by 5.13 K with no load. But in the same conditions, T_p increases by 6.88 K with 100 mW heat load. The condition of controlled temperature of ambient housing has little effect on the sensitivity of second stage temperature changing.

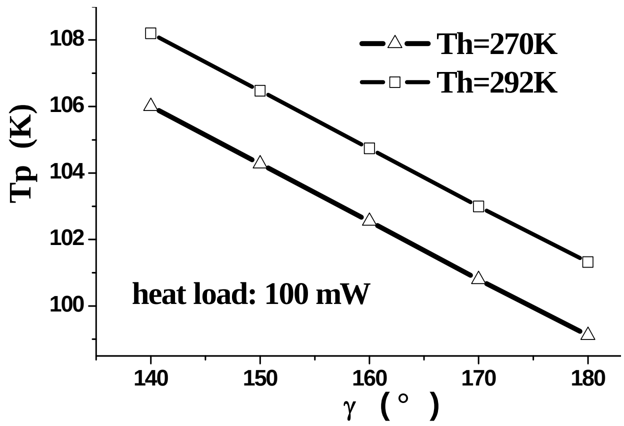

Figure 7 Temperature of second stage under different controlled temperature of ambient housing dependence on view angle

The curve in Fig 7 shows the relation between the temperature of second stage T_p and the view angle in different conditions of controlled temperature of ambient housing. By analyzing this curve, it is found that the radiant cooler can reach the working performance needed by selecting different method to control the temperature of ambient housing when the view angle decreases.

CONCLUSION

When radiant cooler is applied on a spacecraft, in most cases the view angle can not reach the maximum because of some limited conditions. The change of view angle influences the working performance of radiant remarkably. Though the structure and inner heat-exchange of paraboloid W style radiant cooler are very complicated, the fact that the temperature of cold patch changed linearly with the variety of the horizontal view angle was found. This conclusion is very valuable in the thermal and structural design of radiant cooler. Furthermore, changing the temperature-controlling method of ambient housing can reduce this kind of negative affects caused by the decreased view angle.

ACKNOWLEDGMENT

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