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Heat Transfer Analysis for Optimal Design of Radioisotope Thermoelectric Generator

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1. Introduction

Recently, the space development is being actively conducted in Korea. Typically, there are various electronic devices such as sensors, robots and power generators. In general, the space environment is extreme environments and very different from the earth environment. So a new approach is need in the space development and requires a technique having a high degree of reliability. For example, there is radioisotope thermoelectric generator(RTG) using radioisotope that has different mechanism in comparison with solar power as power source. This is a technology that has already been trusted by generator for space in the developed countries. For example, RTG is essential for moon explorer because no other power exist source night of moon.

In this study, we investigated the thermal efficiency according to the structure of RTG. Specifically, the thermal properties were analyzed according to the presence of the shield inside vacuum heat-insulating part of the RTG through the finite element analysis.

2. Methods and Results

This study was carried out a heat transfer using a finite element analysis program in order to investigate the heat transfer distribution according to the structure of RTG.

2.1 FEM(finite element method) model

The RTG is largely composed of the heater unit, thermoelectric devices, vacuum-insulated parts, heat sink. In this study, to determine the temperature distribution in the RTG were set up the day condition of the Moon as an environment variable. The models with and without shield in the vacuum insulation part were designed.

Fig. 1 show the RTG analysis models according to the shield in the vacuum insulation part. Fig. 1 (a) is a structure without a shield and Fig. 1 (b) is a structure with a shield in the vacuum insulation part. For efficiency, the analysis was performed by one-quarter of the full model. The common structure of each model has a heater, thermoelectric devices, heat sink, vacuum-insulated parts, protective case. The shield structure model has a shield in vacuum-insulated part. RTG size used in this study is approximately 200 mm x 200 mm x 260 mm.

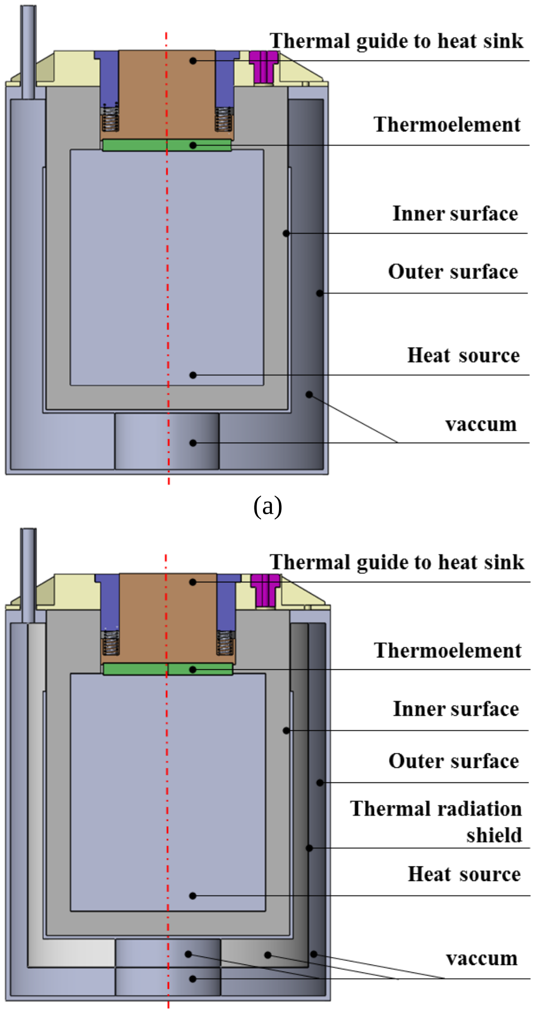

Fig. 1. The RTG models according to shield; (a) without shield, (b) with shield

2.2 Heat transfer analysis

The analysis method is a steady-state thermal analysis, analysis boundary conditions are as follow. The boundary surface of each material was applied to the general thermal conductance value, the uniform emissivity is applied on the inner surface and outer surface of the vacuum-insulated part and surface of the protective case. The heater was set to 120W, the outside temperature was set to 120 ^{o}C which is day of the Moon condition

Fig. 2 show the temperature distribution of the RTG model according to shield. Fig. 2 (a) is the structure without shield and Fig.2 (b) is the structure with shield. In the heater unit, showing the highest temperature and the heat spreads to the insulation part. The temperature difference occurs mostly in the thermoelectric parts. Temperature distribution difference between the two models is incomplete.

Fig. 3 show the radiation difference according to the shield. The value of the radiation from the inner and outer of the vacuum-insulated parts were compared. In the inner case, the radiation values in the shield model are reduced more than in the structure model without shield, approximately 32.6%. In the outer case, the radiation values in the shield model are reduced more than in the structure model without shield, approximately, 68.1%. The difference between the value of the inner and outer radiation within the same structure model is greater in the shied model.

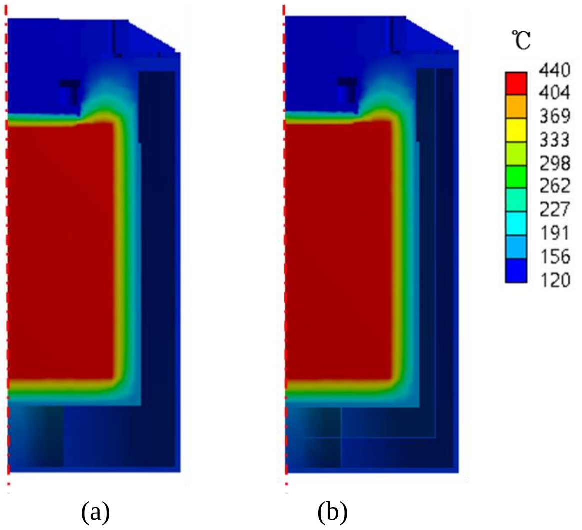

Fig. 2. Temperature distribution of the RTG model according to shield; (a) without shield, (b) with shield

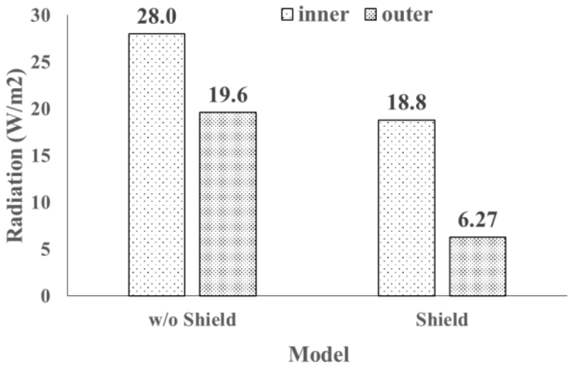

Fig. 3. Radiation value of the inner and outer surface of the vacuum-insulated parts according to shield

3. Conclusions

Finite element analysis was used to analyze the characteristics of the temperature distribution in the RTG models according to the shield. The structure of the shield came out less heat loss than the structure without shield. As a result, the structure with a shield is advantage in the RTG design

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