Prediction of Thickness of Insulation Material inside HSM for the Structural Integrity of HSM using Heat Transfer Analysis

Jong Han Park[a], Kwang Jae Son[a], Jintae Hong[a], Jong Bum Kim[a]*
[a]*HANARO Utilization and Research, Korea Atomic Energy Research Institute (KAERI), Daejeon 305-353, Korea*
**Corresponding author: kjson@kaeri.re.kr*

1. Introduction

RTG(Radioisotope Thermoelectric Generator) is a power generation system using the decay heat of radioisotope, it's the power without being charged from outside, it's utilized for special purposes of space exploration and deep sea exploration. For instance, a RTG called as SNAP-3 utilized in Transit 4A for space exploration[1-4]. These days, the Korea Atomic Energy Research Institute is developing an RTG for aerospace[5].

RTGs for space exploration is required that the structural integrity verification for aerodynamic heating in case of an accident.

In this study, diverse designs of HSM were considered. The optimal thickness of insulation material inside HSM(Heat source module) is predicted for the structural integrity of HSM using heat transfer analysis. The safety criterion is that the maximum temperature of iridium clad do not exceed 1400 °C by aerodynamic heating during 300s.

2. Methods and Results

2.1 FEM models and boundary conditions

Heat transfer analysis for heat source module was conducted by using ANSYS^{TM}.

Fig. 1 shows a cross section of HSM-1 which is initial model. The type of analysis models are 2d axisymmetric, the radiation emissivity of aeroshell surface is set to 0.3, the ambient temperature of them is set to -170 °C. All contact conditions are set to 'bonded'. The material of aeroshell is high density carbon fiber to protect a HSM from aerodynamic heating, and that of sleeve is low density carbon fiber to insulation effect. GIS(Graphite Impact Shell) is consist of high density carbon fiber to impact absorption. The material of protective shell is hastelloy-237 to avoid catastrophic distortion by excess pressure of helium. The material of heat source is ^{238}pu which generate about 10Wth.

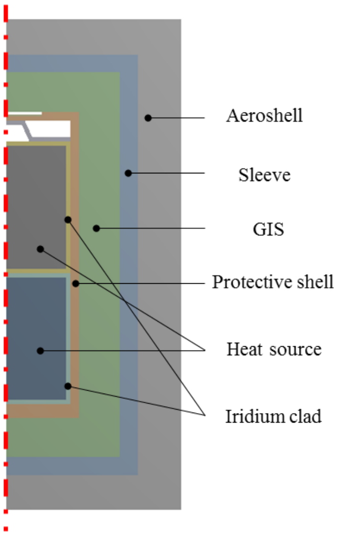

Fig. 1 The cross section of Initial model

2.2 Heat transfer Analysis for Initial Design

Heat transfer analysis for heat source module was conducted by using ANSYS^{TM}.

Fig. 2 shows the maximum temperature of iridium clad for the thickness of GIS and sleeve of HSM-1. In this analysis, the analysis time is set from 50s to 300s at intervals of 50s, the thickness of sleeve and GIS is set from 1 mm to 10 mm. The criteria of safety temperature of iridium clad is set to 1400 °C to keep structural integrity of HSM-1 by aerodynamic heating. As you can see, the maximum temperature exceed 1400 °C in all analysis conditions.

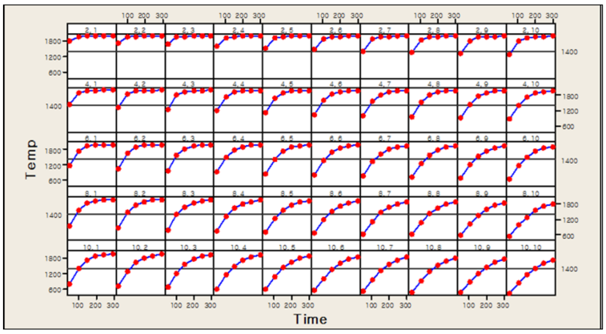

Fig. 2 The result of heat transfer analysis; the maximum temperature of iridium clad of HSM-1 for thickness of sleeve, GIS and time

2.3 Design improvement

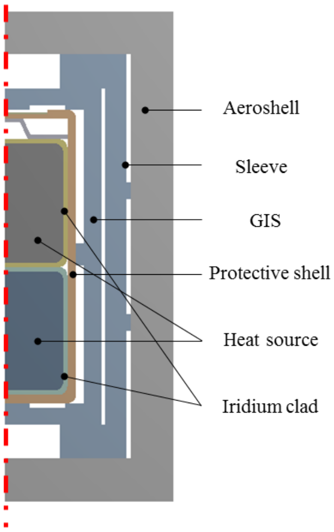

Fig. 3 The cross section of improved model.

Fig. 3 show the cross section of HSM-2 which is improved model from HSM-1 by considering the above result of heat transfer analysis. The insulation effect of HSM-2 is improved by removing the GIS and expanding the sleeve from HSM-1.

2.4 Heat transfer analysis for the Improved Design

Fig. 4 shows the maximum temperature of iridium clad for the thickness of sleeve and analysis time of HSM-2. The input factors(analysis time, thickness range of sleeve) for analysis of HSM-1 is the same as input factors of HSM-1. When the thickness of sleeve_in('A' of fig. 3 (b)) is 5 mm and the thickness of sleeve_out('B' of fig. 3 (b)) is 4 mm, the maximum temperature of iridium clad is 1412 ^{o}C, it's within the error range(±1%).

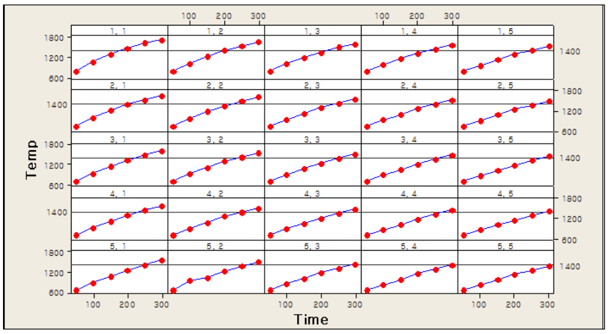

Fig. 4 The result of heat transfer analysis; the maximum temperature of iridium clad of HSM-2 for thickness of sleeve and time

3. Conclusions

In this study, a heat transfer analysis was conducted to find optimal thickness of GIS and sleeve to avoid melting of iridium clad for HSM-1 and HSM-2. The results are as follow.

1) In case of HSM-1, the maximum temperature of iridium clad exceed 1400 ^{o}C in all analysis conditions.
2) In case of HSM-2, the maximum temperature of iridium clad is 1412 ^{o}C, when the thickness of sleeve_in is 5 mm, and the thickness of sleeve_out 4 mm

In conclusion, when the HSM-2 design are applied, the structural integrity of iridium clad of HSM is expected to improve.

ACKNOWLEDGEMENTS

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