Poster Number : P03C07

Optimization of Spent Nuclear Fuels per Canister Based on Decay Heat to Improve Disposal Efficiency

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■ Introduction

- ✓ Disposal area of a deep geological repository is determined based on spacing between deposition holes and disposal tunnels through the thermal analysis.
- ✓ The optimum combination of spent fuel assemblies (SFA) per canister based on decay heat of each SFA is necessary for improving the disposal efficiency.
- ✓ The actual decay heat per canister has to be estimated using decay heat of each SFA instead of using a reference SFA.
- ✓ In this study, we develop a computer program for the optimum combination of SFAs per canister based on actual decay heat data of each SFA considering all SNFs simultaneously.
- ✓ We check the stability and applicability of the program by applying it to the postulated disposal scenarios.

■ Database for Spent Nuclear Fuel (SNF)

- ✓ We collect the SNF data based on the 8th electric power supply and demand.
- ✓ We develop a database for SNF generated from all the PWRs until 2082.
- ✓ Each record consists of ID, Type, Initial_Enrichment wt %), Initial_U_Mass (g), Burnup (MWD/MtU), Discharge_Time, and Storage_Location.

	A	B	C	D	E	F	G
1	ID	Type	Initial_Enrichment	Initial_U_Mass	Burnup	Discharge_Time	Storage_Location
2	KK1A01	14_SFA	2.1	401,525	24,241	1983-04-21	Kori_3
3	KK1A02	14_SFA	2.1	400,564	24,286	1983-04-21	Kori_3
4	KK1A03	14_SFA	2.1	400,088	16,837	1979-11-16	Kori_3
5	KK1A04	14_SFA	2.1	400,018	16,966	1979-11-16	Kori_3
6	KK1A05	14_SFA	2.1	399,039	24,170	1981-02-18	Kori_3
7	KK1A06	14_SFA	2.1	399,542	25,588	1982-05-03	Kori_3
8	KK1A07	14_SFA	2.1	399,595	25,700	1982-05-03	Kori_3
9	KK1A08	14_SFA	2.1	399,973	16,806	1979-11-16	Kori_3
10	KK1A09	14_SFA	2.1	399,859	23,902	1981-02-18	Kori_3

Fig. 1. Example screenshot of a database for SNF

■ Decay heat of SNFs

- ✓ We estimate the decay heat of each SFA using the regression equations.
- ✓ The actual decay heat of each SFA are estimated considering the cooling time and disposal time as well as characteristics data of each SFA.

Table 1. Regression equations and constants for decay heat

	Category	Time (yr)	Equation	Constant
α	Fitting	1~30	$\alpha = y_0 + A_1 \cdot e^{-\left(\frac{x}{t_1}\right)} + A_2 \cdot e^{-\left(\frac{x}{t_2}\right)} + A_3 \cdot e^{-\left(\frac{x}{t_3}\right)}$	y0=4.908966E+02, A1=7.679070E+03, t1=1.797920E+02 A2=1.045528E+03, t2=2.488088E+01 A3=1.322184E+04, t3=8.543600E+01
		30~300	$\alpha = y_0 + A_1 \cdot e^{-\left(\frac{x}{t_1}\right)} + A_2 \cdot e^{-\left(\frac{x}{t_2}\right)}$	y0=4.490509E+01, A1=1.132256E+03, t1=4.379002E+01 A2=2.034482E+02, t2=3.939357E+02
		300~10⁶	$\alpha = a \cdot x^b$	a=8.533352E+03, b=-7.193700E-01
β	Weighting	1~30	$\beta = y_0 + A_1 \cdot e^{-\left(\frac{x-x_0}{t_1}\right)} + A_2 \cdot e^{-\left(\frac{x-x_0}{t_2}\right)} + A_3 \cdot e^{-\left(\frac{x-x_0}{t_3}\right)}$	y0= 17.23509, x0= 0.23599 A1= 1102.09085, t1= 1.29539 A2= 298.05839, t2= 4.41315 A3= 204.66334, t3= 54.00279
		3x10²~ 3x10⁴		y0= 0.27076 , x0= -2511.04593 A1= -733.76391, t1= 3622.04249 A2= 2784.07004 t2= 552.36651 A3= 728.61222, t3= 3663.67428
		3x10⁴~ 10⁶	$\beta = a \cdot x^b$	a= 308.48779, b= -0.68194
γ	Burnup	all range	$\gamma = (Burnup - 35)/5$	
Input variable: [year], Burnup [GWD/MtU]				
Final Output: Decay Heat = $\alpha + \beta \times \gamma$, (Watt/MtU)				

■ Computer program for the optimum combination

- ✓ We develop an algorithm for the optimum combination of SFAs per canister.
- ✓ Using MATLAB program, we developed a computer program, Acom, for the optimum combination of SFAs per canister based on actual decay heat without considering the source of SNFs.
- ✓ We check the stability of the ACom program by analyzing iteratively the overall distribution of decay heats per canister.
- ✓ We apply the ACom program to the disposal scenarios suggested in the research program for the design improvement of a DGR for SNFs.

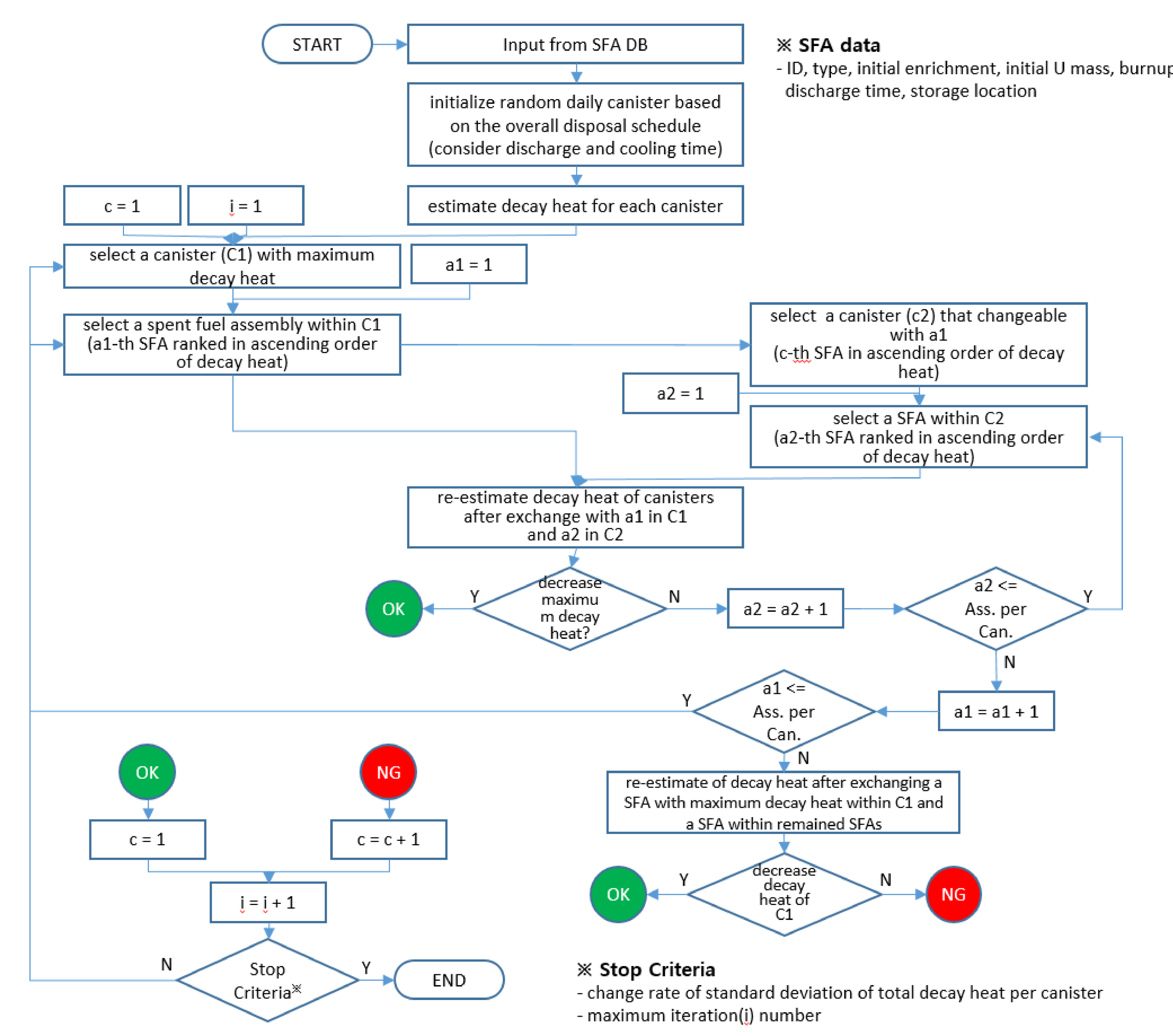
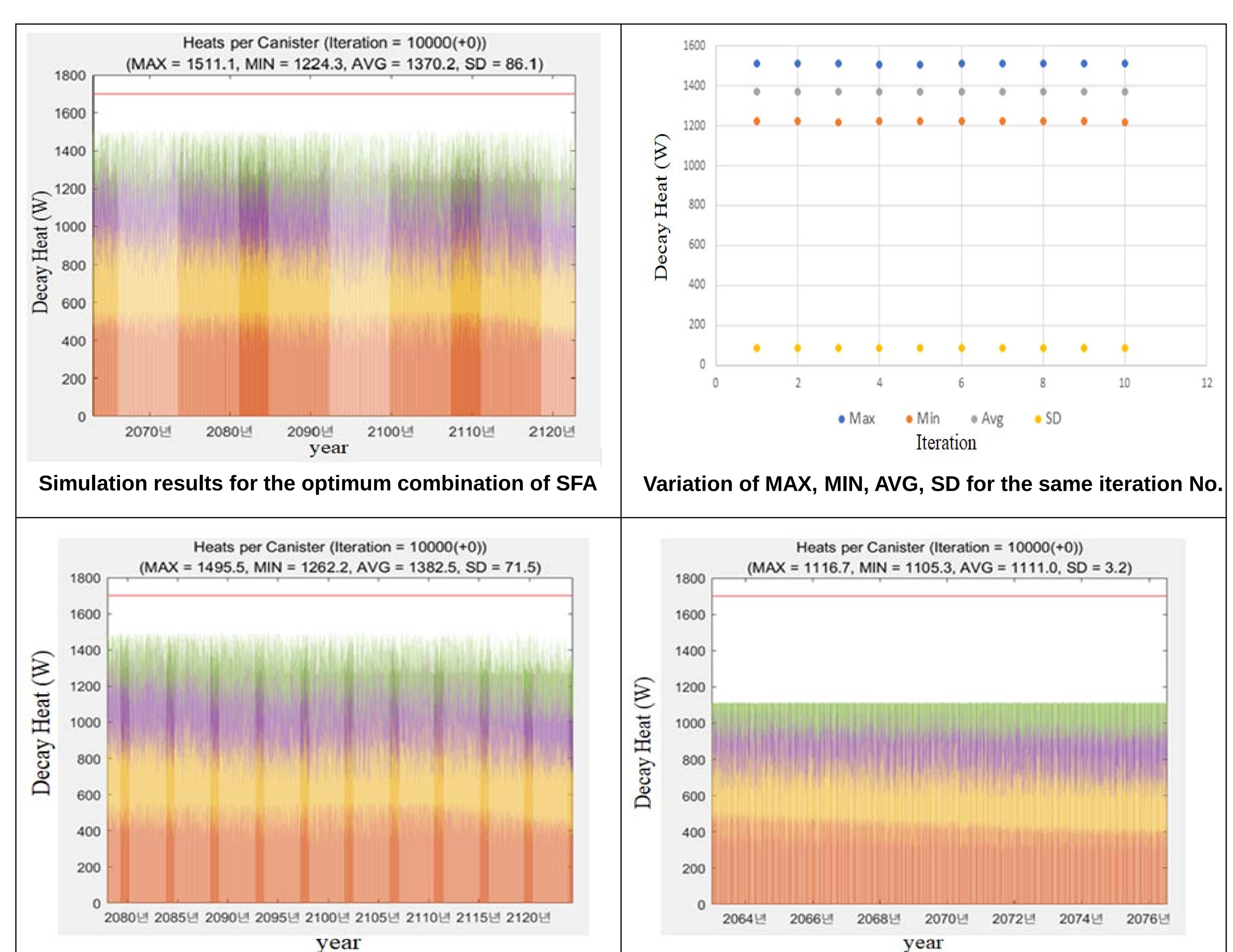


Fig. 2. Algorithm for the optimum combination of SFAs per canister



Simulation results for the optimum combination of SFA

Variation of MAX, MIN, AVG, SD for the same iteration No.

Simulation results for disposal of R-SF

Simulation results for the disposal of S-SF

Fig. 3. Simulation results using the ACom program

■ Summary

- ✓ We develop a computer program for the optimum combination of SFAs per canister using the actual decay heat data of each SFA.
- ✓ We check the stability and applicability of the program by applying it to disposal scenarios suggested in the previous research program.
- ✓ This program can be used for the optimum design of a DGR for SNFs to improve the disposal efficiency.