Comparison of MEDEAC and ORIGEN in Fuel Assembly Depletion Calculation

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1. Introduction

Many kinds of depletion calculation code has been developed for estimation of the radioactive material inventory in the core or spent fuel repository. ORIGEN [1] code has been widely used as a representative of these codes. Korea Atomic Energy Research Institute (KAERI) also has used this code for various core design area. KAERI has developed Matrix Exponential based isotope DEpletion and Analysis Code (MEDEAC) [2] as an alternative to ORIGEN. MEDEAC was developed by improving the capability of the DeCBURN [3,4] program which was originally developed for DeCART [5] depletion calculation. MEDEAC is a radioactive material processing code by solving the burnup equation. The burnup equation is solved by introducing the Krylov subspace method to matrix exponential solution. The burnup matrix is constructed by using the isotopic burnup chain data, cross section data, and fission yield data included in the MEDEAC library. The solution of burnup equation is used to evaluate the isotopic inventory change, the isotopic radioactivity change, and the photon amount.

As a part of code capability verification and validation (V&V) for MEDEAC, a depletion calculation for fuel assembly model was performed. The ORIGEN results are then compared to the MEDEAC results as well as the fine time step results of MEDEAC.

2. Methods and Results

2.1 Fuel Assembly Model for Depletion Calculation

In order to perform depletion calculation using MEDEAC and ORIGEN, typical 17x17 fuel assembly was modelled using DeCART2D [6] code. The assembly consists of 4.75 w/o UO2 fuel pin cells. The initial material compositions of fuel assembly were getting from DeCART2D calculation and used as input for MEDEAC and ORIGEN. Table 1 shows the initial composition of the fuel assembly.

Table 1: Initial composition of 17x17 fuel assembly

Nuc	Mol	Nuc	Mol	Nuc	Mol
H	4.13E+03	Mn	3.35E-01	Mo	7.94E-02
B	1.74E+00	Fe	1.11E+01	Ag	3.55E+01
C	5.53E-01	Co	2.63E-02	Cd	1.93E+00
O	4.22E+03	Ni	2.92E+00	In	6.26E+00
F	4.19E+00	Cu	7.31E-01	U	1.06E+03
Si	2.36E-01	Zr	7.18E+02	-	-
Cr	3.94E+00	Nb	7.85E+00	-	-

2.2 Depletion Calculation

A depletion calculation for fuel assembly model was performed using MEDEAC and ORIGEN. The initial compositions of material were applied to make the input files of these codes. These initial materials were depleted for 300 days. The results of depletion calculation were compared with three solutions. The first solution is REF which is obtained by ORIGEN with the time step size of 10 day and considered as a reference. The second solution is MED which is obtained by MEDEAC with the time step size of 10 day. The last solution is MED_F which is obtained by MEDEAC with the fine time step size of 0.005 day. This solution eliminates the short-lived isotopes, and the result for all isotopes is obtained by matrix exponential method. In order to perform these calculation, ORIGEN libraries were converted using LIBCONV program which is used to convert the ORIGEN libraries to MEDEAC library or vice versa [2]. MEDEAC library includes all information of ORIGEN libraries. Fig. 1 shows how to generate the MEDEAC library. These comparisons include decay heat, radioactivity, some isotopic inventory change for activation products, actinides and fission products.

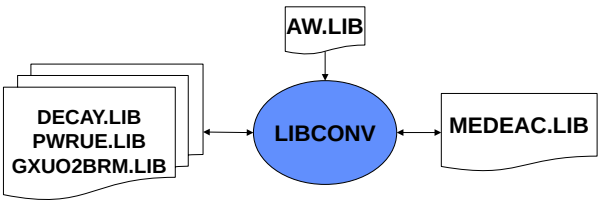

Fig. 1. MEDEAC library generation

2.3 Results

In this section, the results of depletion calculation is examined by comparing with ORIGEN solutions with MEDEAC and MEDEAC with the fine time step size solutions. The solution of the ORIGEN was used as a reference value. Fig. 2 and Fig. 3 present the difference between REF and computed results of decay heat and radioactivity, respectively. In this paper, the difference means relative error of between REF and computed results. The maximum difference are -0.17% and -0.08% in decay heat and radioactivity, respectively. The results show that MEDEAC predicts almost same radioactive data with REF showing a trivial error of about 0.20 %.

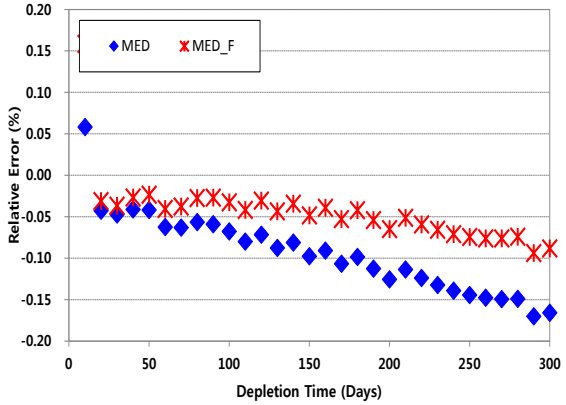

Fig. 2. Difference in decay heat for 300 days

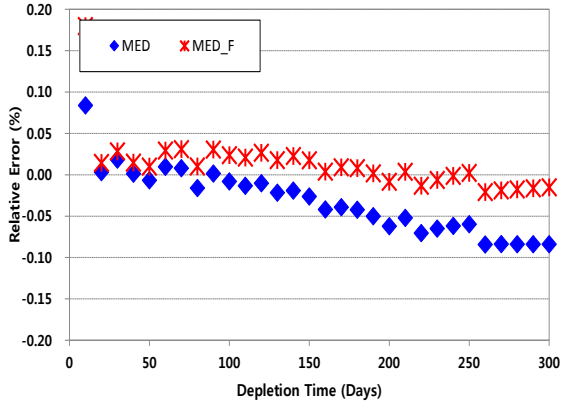

Fig. 3. Difference in radioactivity for 300 days

Table 2 and Table 3 show the difference between REF and computed isotopic inventory of U-235 and Pu-239, respectively. The maximum difference in U-235 is -0.02%, and the maximum difference in Pu-239 is -0.01 %.

Table 2: Difference between REF and computed U-235 inventory

Days	REF	Relative Error, %	
		MED	MED_F
0	5.11E+01	0.00	0.00
30	5.01E+01	0.00	0.00
60	4.92E+01	0.00	0.00
90	4.82E+01	-0.02	-0.02
120	4.73E+01	0.00	0.00
150	4.63E+01	0.00	0.00
180	4.54E+01	0.00	0.00
210	4.45E+01	0.00	0.00
240	4.36E+01	0.00	0.00
270	4.28E+01	0.00	0.00
300	4.19E+01	0.00	0.00

Table 3: Difference between REF and computed Pu-239 inventory

Days	REF	Relative Error, %	
		MED	MED_F
0	0.00E+00	0.00	0.00
10	8.13E-02	-0.01	-0.05
30	3.13E-01	0.00	0.00
60	6.46E-01	0.00	0.00
90	9.57E-01	0.00	0.00
120	1.25E+00	0.00	0.00
150	1.52E+00	0.00	0.00
180	1.78E+00	0.00	0.00
210	2.02E+00	0.00	0.00
240	2.25E+00	0.00	0.00
270	2.46E+00	0.00	0.00
300	2.66E+00	0.00	0.00

Fig. 4 and Fig. 5 present difference between REF and computed isotopic inventory of H-3 and C-14, respectively. Theses isotopes are sum of activation products and fission products. The maximum difference in H-3 and C-14 are -0.10% and -0.12%, respectively.

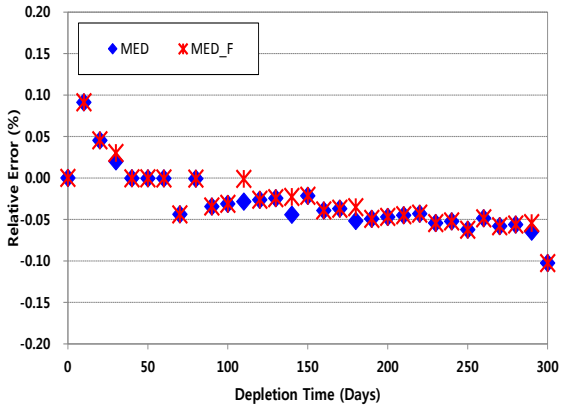

Fig. 4. Difference in inventory of H-3 for 300 days

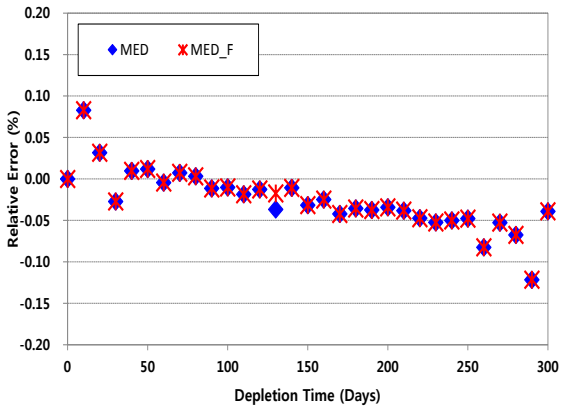

Fig. 5. Difference in inventory of C-14 for 300 days

As one of the activation products, N-16 was compared. The difference of N-16 inventory is presented Fig. 6. The maximum difference in N-16 is -0.09 %.

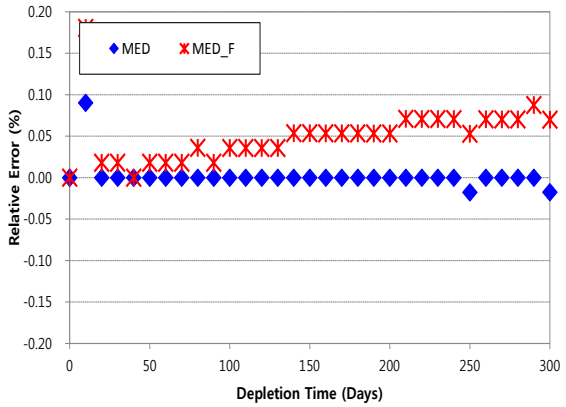

Fig. 6. Difference in inventory of N-16 for 300 days

As one of the actinides, Np-237 was compared. Fig. 7 shows the difference between REF and computed results in Np-237. The maximum differecen is 0.07 %.

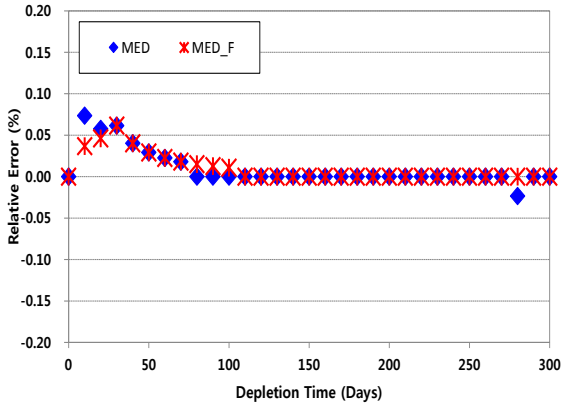

Fig. 7. Difference in inventory of Np-237 for 300 days

In order to compare fission products inventory, Xe-135 and Sm-149 were evaluated. Fig. 8 and Fig. 9 show these results. The maximum differences in Xe-135 and Sm-149 are -0.16 % and 0.12 %, respectively. From the above results, MED predicts almost the same isotopic inventories with REF showing a trivial error of about 0.20 %.

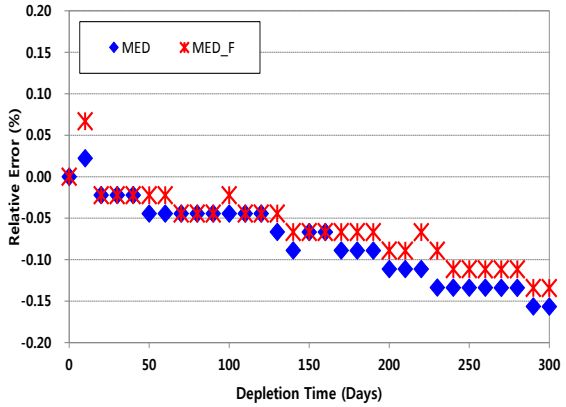

Fig. 8. Difference in inventory of Xe-135 for 300 days

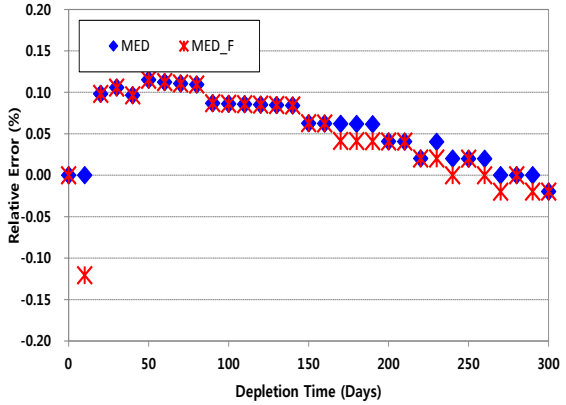

Fig. 9. Difference in inventory of Sm-149 for 300 days

3. Conclusions

MEDEAC is developed for an alternative code to ORIGEN. In this paper, a depletion calculation for typical 17x17 fuel assembly model was performed using MEDEAC and ORIGEN. The results of ORIGEN are examined by comparing with MEDEAC results and MEDEAC results with the fine time step size. Various radioactive data such as decay heat, radioactivity and isotopic inventories. The evaluation of isotopic inventories include activation products, actinides and fission products. The results of estimation have good agreement with the REF data. Also, the results show that MEDEAC estimates the isotope inventory comparably and the radioactive data very closely with ORIGEN. These results mean that performance of MEDEAC is reliable and MEDEAC can be used as an alternative code to ORIGEN.

REFERENCES

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