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Water Boiling Time in a Spent Fuel Pool with Adiabatic and Non-adiabatic Boundary Conditions

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1. Introduction

Spent fuels discharged from nuclear reactors must remain under wet storage into pools awaiting their temperature and radioactivity emission to reach safety values for transportation to the final repository. The temperature and radioactivity levels vary according to each country regulation [1]. The water temperature between 298 K and 310 K in a spent fuel pool (SFP) is maintained by an external cooling system (ECS). Thermal studies must consider hypothetical scenarios of ECS breakdown that would provoke overheating and structural damage in the spent fuels (SF) stored.

Based on the idea of using reprocessed nuclear fuels in conjunction with UO_2 in a PWR [2]-[4], this work evaluates the water boiling time (T_b) in the ECS collapse scenario. UO_2, $(TRU\text{-}Th)O_2$, $(U\text{-}Th)O_2$, and MOX spent fuels were discharged from PWR. Three loading patterns of these kinds of SF assemblies were considered: a single-type loading of UO_2, and mixed loadings containing either a quarter or one third of reprocessed fuels. The modelled SFP consists on the smallest arrangement of assemblies (unit of repetition, UR) that represents each loading pattern of a PWR's SFP. The aim is to determine the influence on T_b of setting the top of the SFP either as adiabatic or non-adiabatic wall.

The simulations were implemented in CFX Ansys and OpenFOAM© codes, and the preliminary results appear to be highly dependent on the boundary condition. Simulations considering the top of the SFP as non-adiabatic yield higher T_b values.

2. Methodology

The heat sources in simulations are the SF and were derived from previous studies [5]. The main characteristics of SFs of interest in the present work, including the final amount of fissile material, the burnup and the operation time of the reactor were obtained from [5], and are listed in following:

- UO_2: enriched to 4.3 w/o 235U/U; burnup of 48 GWd/tHM during 3.61 years and 1.634% of final amount of fissile material.
- $(TRU\text{-}Th)O_2$: fuel composed of 10 % of Th and 90 % of reprocessed fuel by UREX+, with 9.53 % of fissile material; burnup of 48 GWd/tHM during 3.61 years and 6.657 % of final amount of fissile material.
- MOX: enriched to 0.25 w/o 235U/U; burn-up of 48 GWd/tHM during 3.61 years and 3.375 % of final amount of fissile material.
- $(U\text{-}Th)O_2$: Enriched to 4.869 w/o 235U/U; burn-up of 48 GWd/tHM during 3.61 years and of 2.084

% final amount of fissile material.

Each assembly of SF was modelled as a solid cylinder, and only a single UR is represented. To determine the volume of water in the model, the proportion SF/water in the real pool of the PWR fully filled with assemblies was adopted, i.e., 0.0508 [6].

The following studies were conducted considering the modelled SFP loaded according to the loading pattern 1:2:

- Case I: three cylinders of $(TRU\text{-}Th)O_2$ and six of UO_2;
- Case II: three cylinders of $(U\text{-}Th)O_2$ and six of UO_2;
- Case III: three cylinders of MOX and six of UO_2;
- Case IV: nine cylinders of UO_2.

For the SFP filled according to the loading pattern 1:3:

- Case V: one cylinder of $(TRU\text{-}Th)O_2$ and three of UO_2;
- Case VI: one cylinder of $(U\text{-}Th)O_2$ and three of UO_2;
- Case VII: one cylinder of MOX and three of UO_2;
- Case VIII: four cylinders of UO_2.

Fig. 1 shows an example of the modelled SFP containing the assemblies of SF.

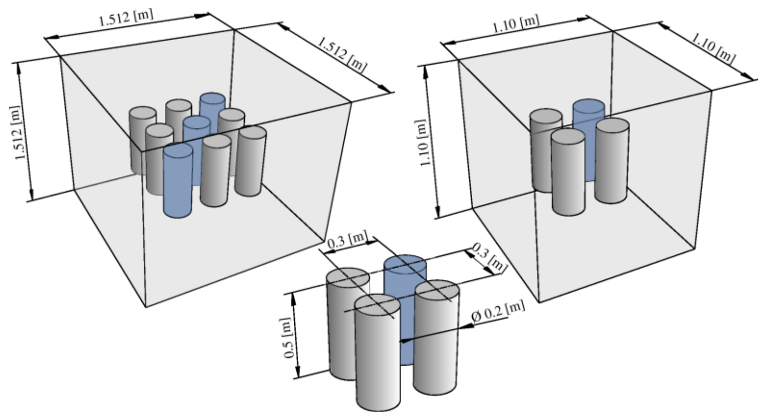

Figure 1: The modelled SFP containing blue cylinders that represent assemblies of $(TRU\text{-}Th)O_2$ or $(U\text{-}Th)O_2$ or MOX, and grey cylinders representing assemblies of UO_2.

The initial and boundary conditions are shown in Fig. 2. They are the same for the loading pattern 1:2.

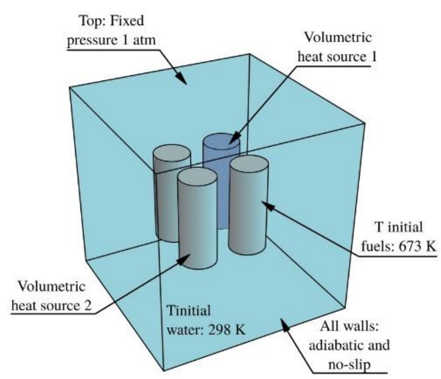

Figure 2: The boundary and initial conditions of the model.

All the simulated cases were also carried out setting the top of the SFP as non-adiabatic.

3. Preliminary Results

Preliminary results show that both Ansys CFX and OpenFOAM yield T_b values ranging from 4.05 h to 5.97 h, when all the SFP walls were set as adiabatic. Contrarily, when the top was set as non-adiabatic, T_b extended to more than 12 h, for most simulated cases.

Fig. 3 shows the temporal behaviour of the water temperature for the loading pattern 1:3.

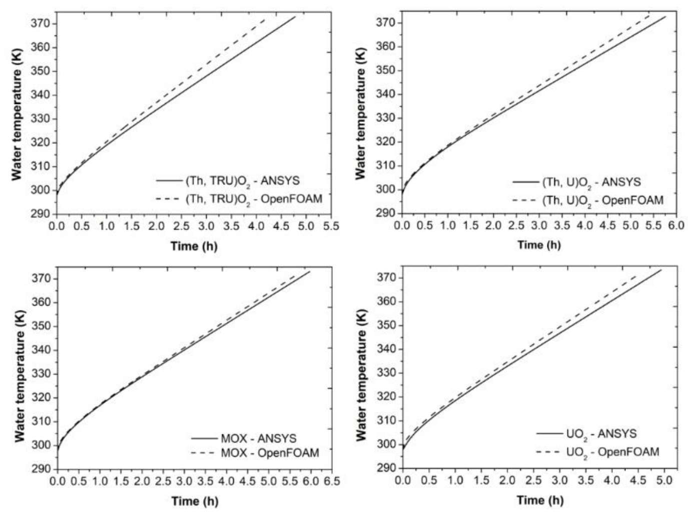

Figure 3: Water temperature behaviour when SFP is loaded according to the pattern 1:3.

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