NEUTRONIC ANALYSIS OF A CORE DESIGN BASED ON AP300 MODEL USING OPENMC

W. DRIDI S. MOUMNI

Laboratory of Energy and Matter for Development of Nuclear Science (LR16CNSTN02), National Centre of Nuclear Science and Technology Sidi-Thabet, Tunisia

ABSTRACT

The study was focused on the analysis of light water Small Modular Reactor (SMR) with a square-shaped fuel element. The core design, based on the Westinghouse UO_2 SMR with less than 5% enrichment was developed using the open-source Monte Carlo (OpenMC) code. Neutronics analyses of the core with UO_2 fuel was achieved to characterize parameters such as the radial neutron flux profile, the maximum to average flux ratio, and the reactivity coefficient, which confirmed good performance. The preliminary results of the simulation are compared to MCNP calculations developed by Missouri S&T.

INTRODUCTION

In this paper, we are interested in a basic neutronic analysis of Westinghouse's AP300 Small Modular Reactor (SMR). Smaller and more adaptable nuclear fission reactors are a trend that SMRs are bringing back. They may offer economical, dependable, and clean power solutions for everything from industrial operations to remote sites. These nuclear reactors have the capacity to generate low-carbon baseload power, which implies that they won't be entirely dependent on fossil fuels to deliver a steady and reliable source of energy. The SMR AP300 is one of the more intriguing emerging ideas that uses light water.

METHODS AND ET MATERIALS

Description of AP300

The American SMR development known as the AP300 reactor combines creative design elements with technical engineering answers to provide a very safe and competitive reactor. AP300 is designed by Westinghouse and inspired from AP1000. The integral type PWR AP300 is based on the indirect steam cycle and has an integrated primary cooling system with pressurized natural circulation, and passive safety features.

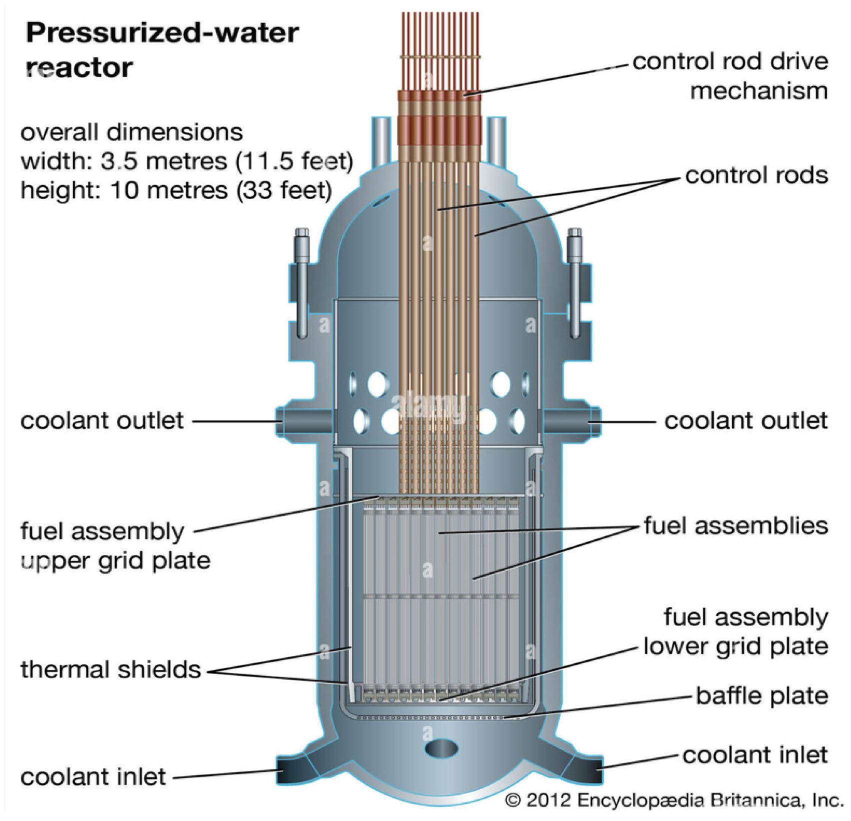


Figure 1. AP300 DESCRIPTION.

OpenMC Modelling

The development process of OpenMC emphasizes transparency, as it is an open-source transport code with fully visible source code. This transparency is particularly beneficial for new users, allowing them to better understand and engage with the software. This research were implemented using version 0.14.0.

Fuel Rod

Material	Radius [cm]
UO_2	0.409575
Helium	0.417830
Zirconium	0.474980

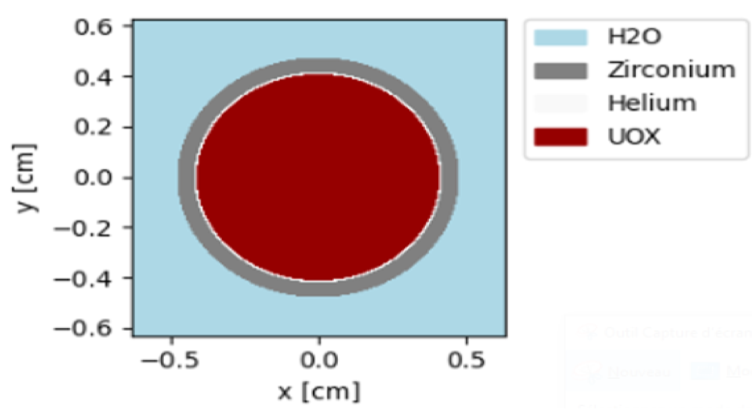
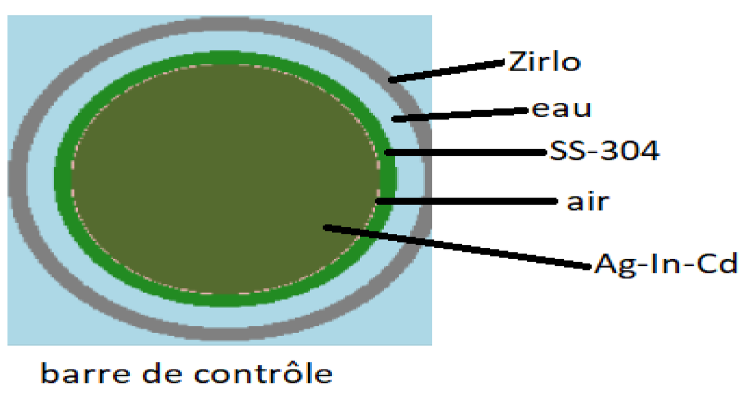


Figure 2. Pencil model with cladding using OpenMC.

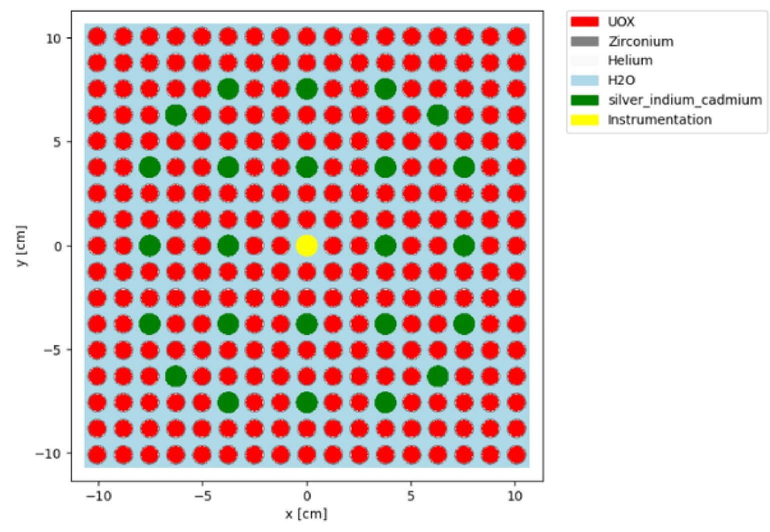
Control Rods

Material	Radius [cm]
Ag-In-Cd	0.43307
Air	0.43688
SS-304	0.48387
Water	0.56134
Zirconium	0.61214



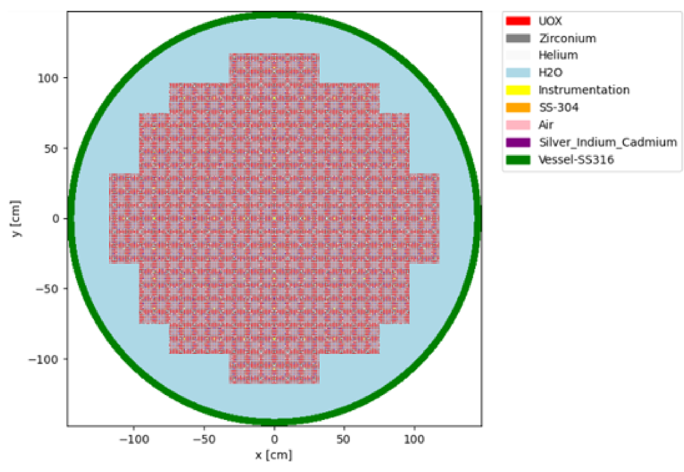
Assembly Configuration

Parameter	Value
Fuel rods per assembly	17 ×17
Rod Pitch	1.26 cm
Fuel Stack Height	244 cm
Rod Height	305 cm



Core Geometry

Core	
Number of assembly	11 ×11
Structure material	
Baffle plate material	SS304
Core barrel material	SS304
Neutron shield panel material	SS304
Pressure vessel material	SC508



PRELIMINARY RESULTS

Neutronic parameters

- β_{eff} est de 0.0068.
- The negative value indicates that any positive reactivity induce increasing temperature rapidly.
- A negative reactivity coefficient helps reactor self-regulate
- A greater fuel reactivity coefficient can result in the Doppler Effect.

Table 1. Neutronic Parameters of AP300.

Details	Our study	DSOUZA
Effective multiplication factor	1.1881 ± 0.00025	1.11945 ± 0.00014
Maximum to average flux ratio	2.672	2.807
Delayed neutron fraction	0.0068	0.00671
Control rod worth	0.1630	0.1715
Fuel coefficient of reactivity ($\delta k/°C$)	-2.24×10^{-5}	-2.58×10^{-5}
Moderator coefficient of reactivity ($\delta k/°C$)	-1.45×10^{-3}	-1.57×10^{-3}

Normalized radial neutron flux

- The uniform distribution results from the loading of fuel and absorber.
- The high source of heat generation is indicated by the maximum neutron flux at the core center.
- The surrounding area, especially the 2.35 enriched UO_2 fuel assemblies, with a higher flux.
- The flux in the cores was shaped or flattened using a combination of reflector conditions (light water) and zoning (variation in fuel or poison).

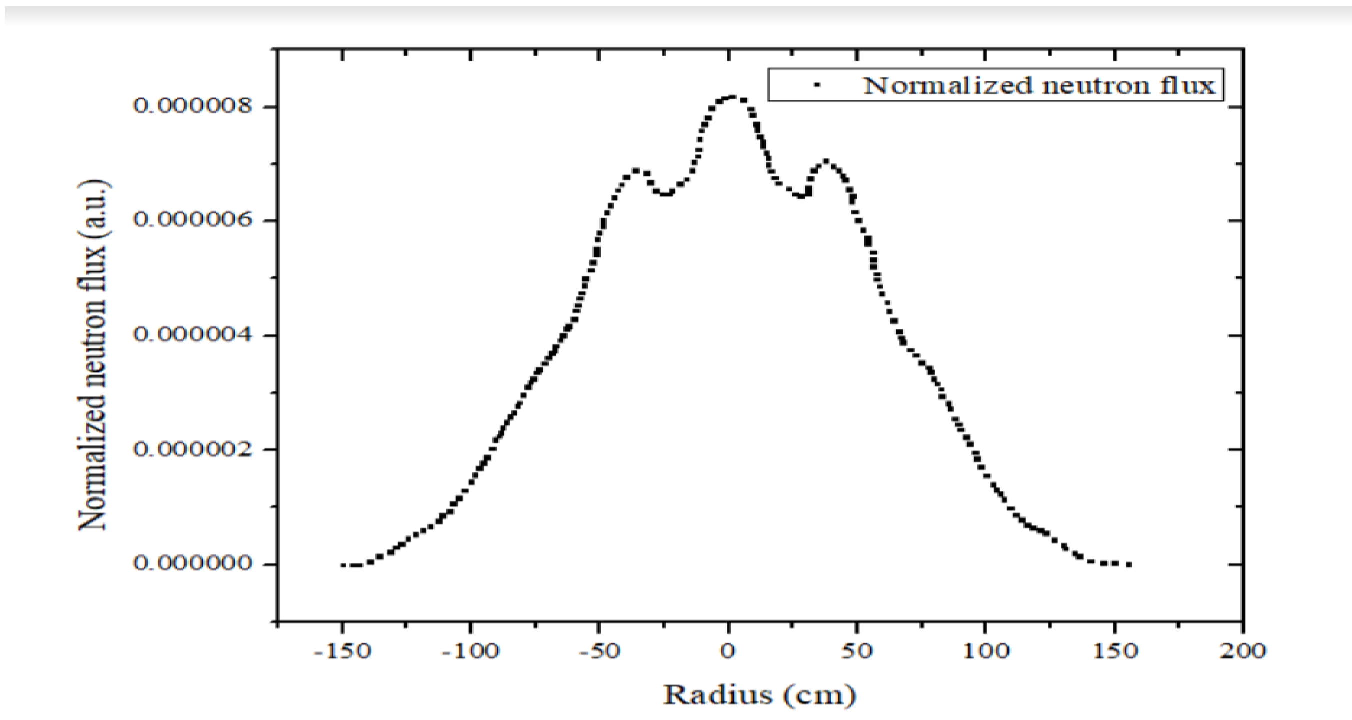


Figure 3. Normalized radial neutron flux.

CONCLUSION

In this research, the study is focused on the conceptual design and the neutronic characteristics of SMR model based on AP300 fuel design. The 3-D model was carried out using OpenMC code owing to assess k_{eff}, neutron energy spectra and spatial neutron flux distributions. The main conclusions conducted by these calculations are.

1. ENDF-B.VII, the newer cross section data library, overestimates the k_{eff} in comparison to use DSOUZA results about 1.1881±0.00025.
2. Maximum to average flux ratio 2.672, Delayed neutron fraction 0.0068, Control rod worth 0.1630, Fuel coefficient of reactivity -2.24E-05 δk/°C), Moderator coefficient of reactivity -1.45E-03 δk/°C.
3. The neutron flux keeps symmetrical shapes.