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# Investigation of some neutronic calculations for vanadium carbide cladding material in a boiling water reactor modelling

*Mehtap Düz*

İnönü University, Faculty of Arts and Sciences, Department of Physics, Malatya, Turkey

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**Abstract:** In this study, a boiling water reactor was modelled and Vanadium Carbide (VC) was used as cladding material in the design. In the designed reactor core, small squares lattices were placed in square lattices. Neptunium mixed fuel rod, VC cladding material, water cooler were used in each small square lattice. $NpO_2$ and $NpF_4$ fuels were used as the Neptunium mixture in the fuel rods. In this study, the criticality ($k_{eff}$), neutron flux, fission energy, heating and deposition values were investigated for the VC cladding material. In the research, the reactor design was made in three dimensions using MCNPX-2.7.0 Monre Carlo code and ENDF/B-VII library.

**Keywords:** Keff, MCNPX-2.7.0, cladding material.

## 1 Introduction

Fission reactors developed with the discovery of the fission reaction constitute all of the existing reactors in operation in the world. Light water reactors (LWR) from fission reactors; boiling water reactors (BWR) and pressurized water reactors (PWR) [1,2]. While fission reactors have the advantage of high energy production with the use of uranium fuel, they have a disadvantage with long half-life waste. From the fission reactors, uranium (about 95 wt%), plutonium (0.9 wt%), minor actinides; Np, Am and Cm (0.1 wt%) and fission products such as Cs, Sr, Tc and I (4 wt%) are left as nuclear waste [3,4]. It is desirable to transform these long half-lived wastes into stable or short half-life cores.

The fact that the uranium fuel reserve will be depleted in the near future has led the scientific world to seek new alternative fuels in fission reactors. Studies have shown that minor actinides released as waste have high power and radiotoxicity. For this reason, recent studies have focused on the production of alternative fuels by reusing minor actinides left as waste as fuel in fission reactors. Thus, it is thought that the amount of minor actinide waste will decrease as well as energy and fuel production.

The select of fuel cladding is an important parameter in reactor physics. Fuel cladding material; it should have low neutron absorption cross section, resistant to any corrosion, and low cost characteristics [5-8]. In this study, VC (5.1 barn) [9] cladding material with these properties was used as clad around the fuel rod to generate energy.

In this study, using $NpO_2$ and $NpF_4$ as fuel to reduce minor actinide amount and VC as cladding material for low thermal neutron cross section, a three-dimensional BWR reactor core design was made with Monte Carlo method and some neutronic calculations were investigated.

* Corresponding author e-mail: mehtap.gunay@inonu.edu.tr
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## 2 Material and methods

In this study, the designed reactor is in the form of a core cylinder. The radius of the cylinder is 264.08 cm and its height is 365.76 cm. 5 cm thick SS316LN ferritic steel was used as reflector and $B_4C$ as control rod. In Figure 1, the reactor core was divided into 8x8 square lattices, each 30.48 cm wide. A 7x7 small square lattice, each 1.94084 cm wide, was placed in each square lattice. In Figure 2, 0.2-1% $NpO_2$ and $NpF_4$ fuel rod radius is 0.60579 cm, gap width is 0.01524 cm, VC clad radius is 0.71501 cm.

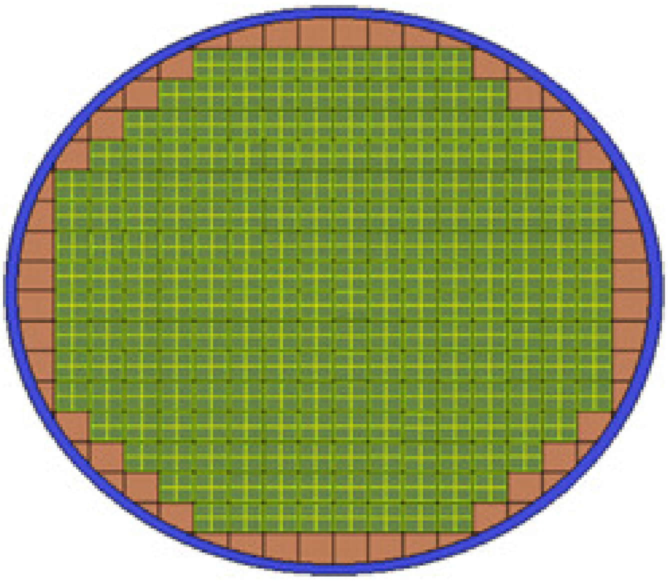

**Fig. 1:** Reactor core design

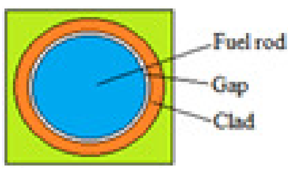


**Fig. 2:** Cell geometry

Monte Carlo method used in the study; it is a computer program that models a complex event or experiment using statistical methods. Since it is a powerful method, it is used to calculate the properties of multi-element systems. Monte Carlo method is a method in which random numbers are generated and accordingly, it is desired to simulate predicted processes. Similarities are tried to be established in order to solve the problem by considering the possibilities. When combined with the MCNP code, which is successful in radiation transmission at low energies in nuclear engineering, with the LAHET (Los Alamos High Energy Transport) code used in high energy radiation transmission, the particles can be transmitted fully at almost all energies. MCNPX; it was created by combining MCNP and LAHET codes. The combination of the two codes, MCNPX, has allowed full radiation transmission in high energy applications in nuclear engineering [10,11].

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## 3 Results

In this study, $k_{eff}$, neutron flux, fission energy, heating and deposition values were calculated for VC cladding material and $NpO_2$ and $NpF_4$ fuels.

Figure 3-7 shows $k_{eff}$, neutron flux, fission energy, heating and deposition for VC cladding material and $NpO_2$ and $NpF_4$ fuels. As can be seen from Figure 3-7, as the fuel ratios for VC cladding material increase, $k_{eff}$, neutron flux, fission energy, heating and deposition increase respectively. For VC cladding material, the highest $k_{eff}$, neutron flux, fission energy, heating and deposition were obtained from 0.75% $NpO_2$ fuel, and the lowest $k_{eff}$, neutron flux, fission energy, heating and deposition were obtained from 0.65% $NpF_4$ fuel.

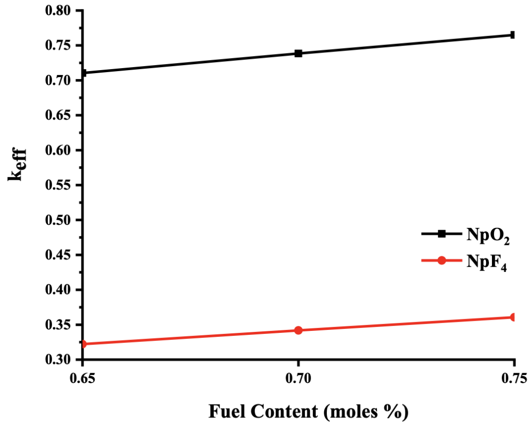


**Fig. 3:** $k_{eff}$ values for VC clad, the fuel components $NpO_2$ and $NpF_4$.

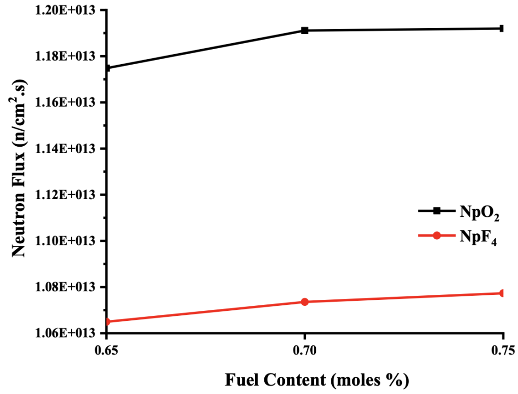


**Fig. 4:** The neutron flux values for VC clad blah the fuel components $NpO_2$ and $NpF_4$

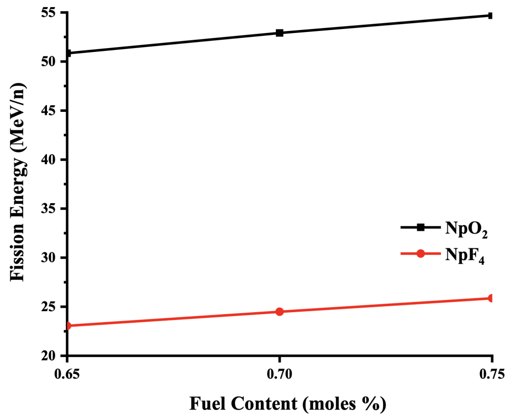


**Fig. 5:** The fission energyvalues for VC clad, the fuel components $NpO_2$ and $NpF_4$

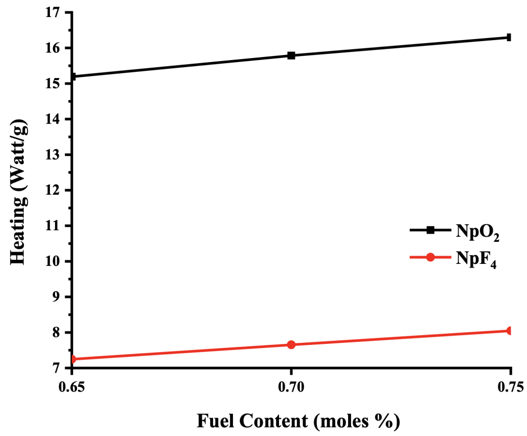


**Fig. 6:** The heating values for VC clad, the fuel components $NpO_2$ and $NpF_4$

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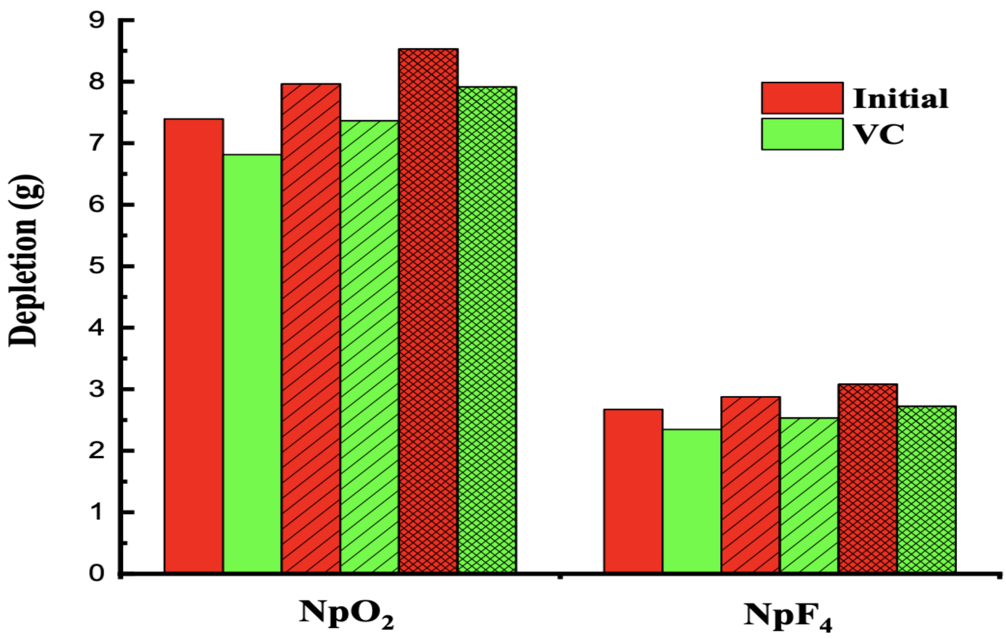


**Fig. 7:** The depletion values for VC clad, the fuel components $NpO_2$ and $NpF_4$ (0.65% , 0.7% , 0.75% )

## 4 Conclusion

In this study, $k_{eff}$, neutron flux, fission energy, heating and deposition values were calculated by using $NpO_2$ and $NpF_4$ fuels for VC cladding material. In the study, MCNPX-2.7.0 Monte Carlo code and ENDF/B-VII library were used for three-dimensional BWR design.

When 0.75% $NpO_2$ fuel was used for the VC cladding material, the $k_{eff}$, neutron flux, fission energy, heating and deposition values were higher than $NpF_4$. As a result; based on the data obtained from neutronic calculations, it can be said that it is more appropriate to use VC clad $NpO_2$ fuel in BWR reactors.

## Competing interests

The authors declare that they have no competing interests.

## Authors' contributions

All authors have contributed to all parts of the article. All authors read and approved the final manuscript.

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