ANALYSIS ON K_{eff} FUEL ARRANGEMENT OF PUSPATI TRIGA REACTOR CORE WITH ADDED MASS OF THORIUM FUEL IN REACTOR CORE

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ABSTRACT

This paper used thorium and uranium zirconium hydride (U-ZrH$_{1.6}$) as fuels for the PUSPATI TRIGA Reactor (RTP) and arranged with different core configuration. It was simulated using Monte Carlo N-Particle (MCNP) Transport code with addition of 2, 20 and 39 thorium fuel rods. In the simulation, thorium fuel rods were placed together with U-ZrH$_{1.6}$ fuel rods in different variations, which have a different thorium mass. Results, such as, effective criticality k_{eff} estimated and compared to those of the experimental and simulation of the original core RTP. The buildup uranium-233 are calculated for each configuration. Arrangement of seed blanket configuration gives the similar result with the original core RTP.

ABSTRAK

Makalah ini menggunakan thorium dan uranium zirconium hydride (U-ZrH$_{1.6}$) sebagai bahan api untuk PUSPATI TRIGA Reactor (RTP) dan diatur dengan konfigurasi teras yang berbeza. Ia disimulasi menggunakan kod pengangkutan Monte Carlo N-Zarah (MCNP) dengan penambahan rod bahan api 2, 20 dan 39. Dalam simulasi, rod bahan api torium diletakkan bersama-sama dengan rod bahan api U-ZrH$_{1.6}$ dalam pelbagai variasi, yang mempunyai massa torium yang berbeza. Keputusan, seperti, kritikal yang berkesan akan dianggarkan dan dibandingkan dengan yang dilakukan oleh eksperimen dan simulasi RTP teras asal. Penumpuan uranium-233 dikira untuk setiap konfigurasi. Pengaturan konfigurasi selimut benih memberi hasil yang serupa dengan teras RTP asal.

Keywords: RTP, thorium, uranium, hydride, MCNP

INTRODUCTION

In 2014, Malaysia launched thorium flagship program that was intended to use thorium element as a nuclear fuel through research and development program [1]. The mixture of thorium with uranium is one of the solutions to get the new type of nuclear fuel. Thorium which is a fertile material, needs to be transmuted into fissile material, uranium-233 [2]. The transmutation process uses neutron to change elements into another form. As for thorium transmutation, thorium-232 absorbs neutrons and changes the element into thorium-233 and undergoes several processes of decay and resulting in the formation of uranium-233 [2]. One of the suggestions is mixing thorium-232 in PUSPATI TRIGA Reactor (RTP) core with uranium fuel.

PUSPATI TRIGA Reactor (RTP) uses uranium zirconium hydride ($U\text{-}ZrH_{1.6}$) fuel that consists of 8.5 wt.%, 12 wt.% and 20 wt.% uranium, which has 20% uranium-235 [3_ENREF_2, 4_ENREF_3]. It is the only research reactor in Malaysia that has been operated since 1982. The 1 MW pool-type reactor achieved its criticality since 28th of June 1982 and it has been the platform to conduct research related with neutron applications [5].

METHODOLOGY

The core was designed and simulated using MCNPX code and the arrangement followed the Core 1 of RTP [6]. For this simulation the original core followed configuration A. It consists of 86 rods of uranium zirconium hydride ($U\text{-}ZrH_{1.6}$) with weight percentage of 8.5 wt.% for each rod. Figure 1 shows the example arrangement of thorium and uranium fuel rods in the RTP core.

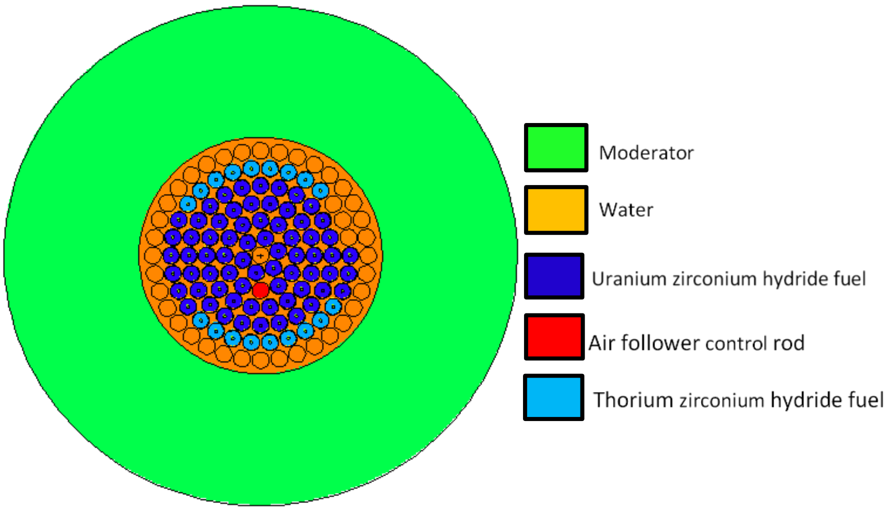
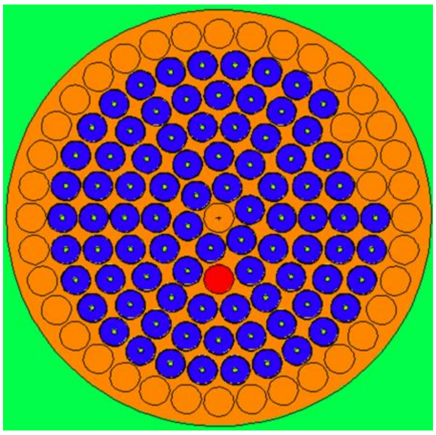
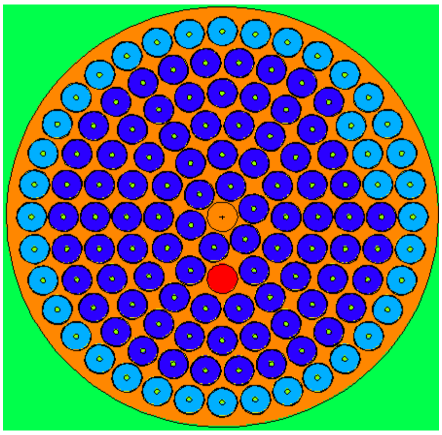


Figure 1: Arrangement of thorium fuel in RTP core

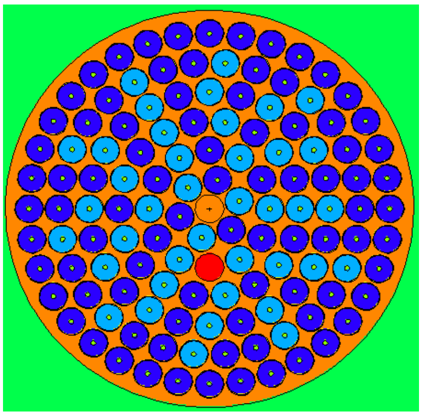
Twelve configurations were designed and simulated with each main configuration has different arrangements and amount of thorium fuels. Starting with configuration B, C, D, and E, the minimum number of thorium fuel is 2 and the maximum number of thorium fuels is 39 fuel rods. Each configuration is labelled with B2, B20 and B39 for configuration B. Configuration C consists of C2, C20 and C39 while configuration D with D2, D20 and D39 and configuration E with E2, E20 and E39. The numbers beside the label represent the total number of thorium fuel rods in the core. Configuration A is not investigated based on the mass parameter because the core is in the original state. Figure 2 shows the different arrangements of core configuration.



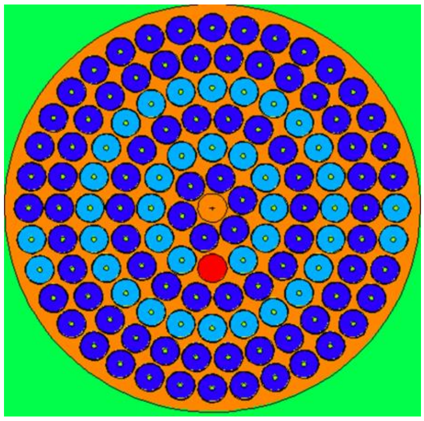
Configuration A



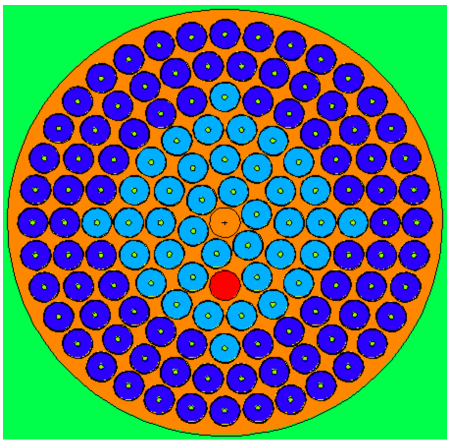
Configuration B



Configuration C



Configuration D



Configuration E

Figure 2: Arrangement of configuration core

Table 1: Configuration fuel arrangement vs. mass of thorium fuel

Configuration	**2 thorium fuels**	**20 thorium fuels**	**39 thorium fuels**
A	-	-	-
B	B2	B20	B39
C	C2	C20	C39
D	D2	D20	D39
E	E2	E20	E39

In order to compare simulation result, preliminary simulation of the original RTP core has been conducted and and k_{eff} obtained for the configuration is 1.05139 [7].

RESULT AND DISCUSSION

There is a total of 4 different fuel arrangements (Configurations B to E) that have been simulated for 1000 burnup days with 2500 neutrons per second and 550 cycles using MCNPX. For each arrangement, the number of thorium fuel rods is also varied to 2, 20, and 39 fuel rods, as shown in Table 1. The fuel that is used in the variable is thorium zirconium hydride fuels. Table 2 shows the result that has been obtained from the simulation.

Table 2: Simulation result fuel arrangement vs. mass of thorium fuels

Configuration	$\boldsymbol{k_{eff}}$		
	Beginning of cycle (BOC)	**Lifecycle (days)**	**Slope**
Core #1	1.05139	289	-0.00016
B2	1.05204	291	-0.00016
C2	0.91083	-	-0.00016
D2	0.90202	-	-0.00015
E2	0.88405	-	-0.00014
B20	1.05062	286	-0.00016
C20	0.88839	-	-0.00014
D20	0.87851	-	-0.00013
E20	0.88373	-	-0.00014
B39	1.04942	276.5	-0.00015
C39	0.86591	-	-0.00012
D39	0.86051	-	-0.00012
E39	0.87721	-	-0.00013

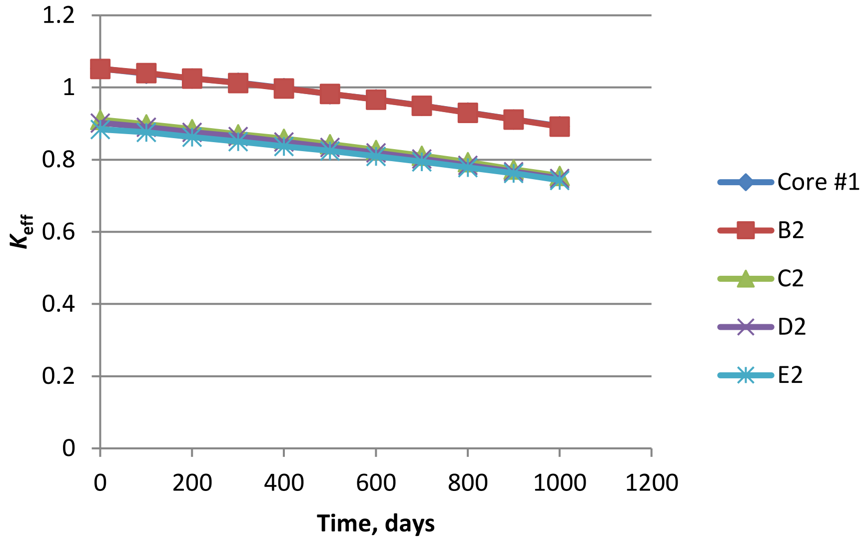


Figure 3: Comparison of k_{eff} for configurations with 2 thorium fuel rods.

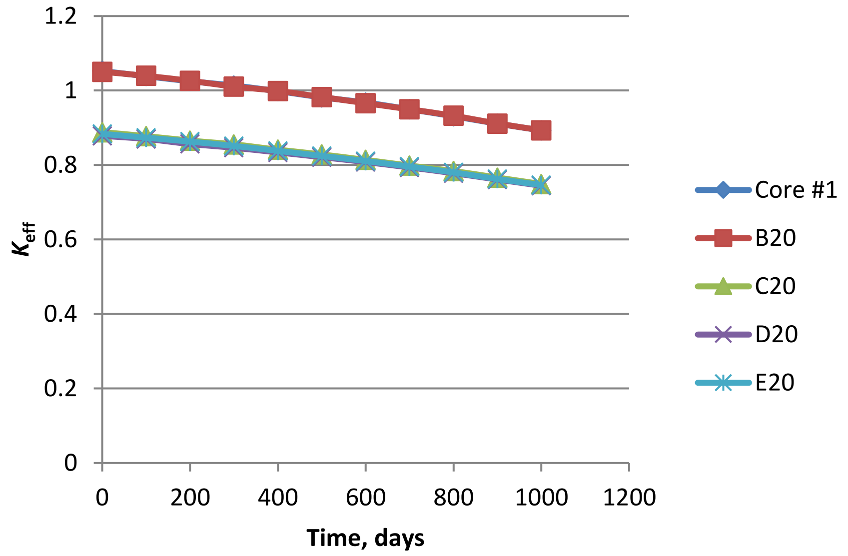


Figure 4: Comparison of k_{eff} for configurations with 20 thorium fuel rods.

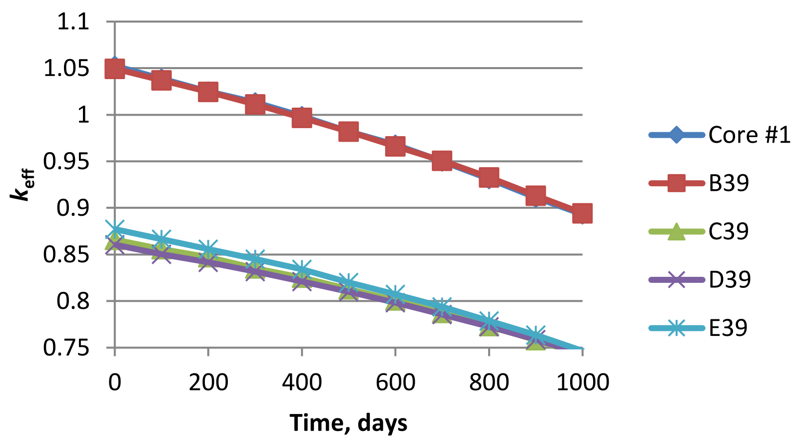


Figure 5: Comparison of k_{eff} for configurations with 39 thorium fuel rods.

Based on all three graphs shown, results show that type B configuration is the best configuration in the variation of mass category. Figures 3, 4 and 5 show that the k_{eff} values for all type B configurations are at the top, which are quite close to the original core #1. The arrangement B has the thorium situated at the outermost side of the core. Hence, this might improve the thermal flux distribution inside the core, generating more neutrons inside the core. The value of the slope of all configurations are different from each other with the range of -0.00012 for core-C39 and core-D39 to -0.00016 for core-B2 and core-C2.

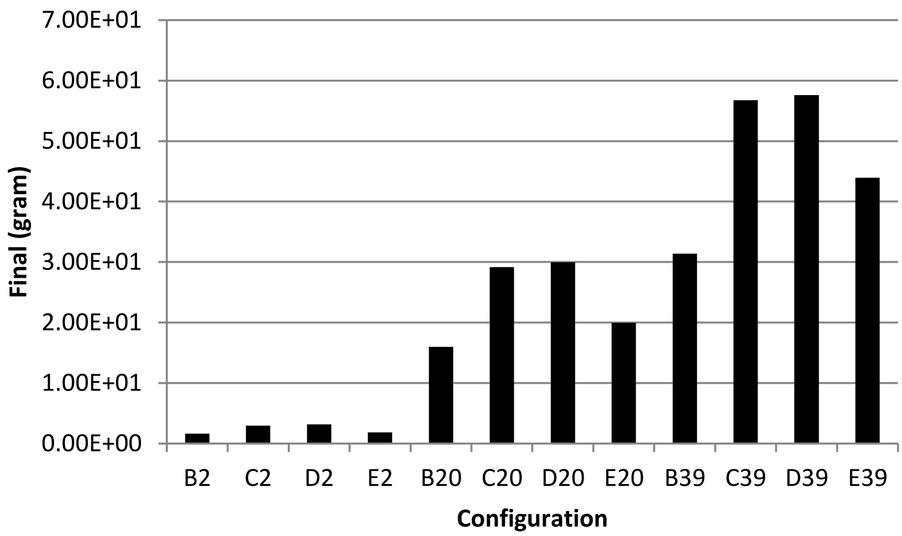


Figure 6: Uranium-233 buildup in gram

Figure 6 above shows the buildup of uranium-233. It shows that configurations B and C have the highest mass of uranium-233 at EOC. This might be due to the neutron flux distribution in those configurations that causes the mass of uranium-233 to increase, although k_{eff} values are low.

CONCLUSION

In conclusion, configuration B offers the similar value of k_{eff} with core#1. This is because the arrangement of configuration B has the same configuration as seed blanket configuration. The configuration gives the constant amount of neutron flux distribution in the core which resulting similar k_{eff} value with the RTP original core.

ACKNOWLEDGEMENT

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