Comprehensive study of Lattice cell calculations for thorium based fuel cycle in light water reactors using srac code

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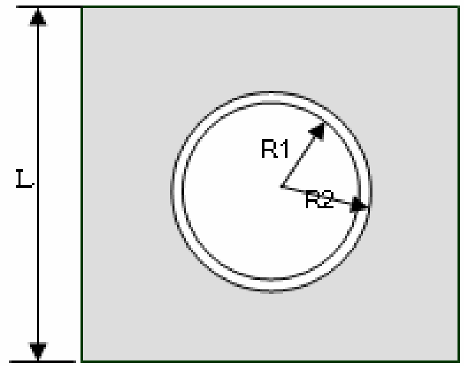
1. Introduction.

- Nuclear fuels used in reactors can be 235-U, 239-Pu and/or 233-U. 233-U produced from 232-Th in the neutronics point of view is one of the best isotope in the fissionable isotopes.
- In all energy range, neutron fission yield ratio (η) and the number of neutron absorbed are higher than those of 235-U and 239-Pu, so that 233-U could be used as fuel for many kind of reactor.
- Thorium oxide ThO_2 has greater stability and can be used with high temprature, longer durability due to its melting point of 3050^{o}C (UO_2 : 2700 – 2800^{o}C) that expected to gain high burnup.
- One of the advantages of 233-U as compare with 235-U and 239-Pu is that the higher neutron emitted yield when one neutron absorbed.
- In this study, from reactor physics calculation aspect, our work focuses on estimation of nuclear fuel conversion of 233-U and those of uranium or MOX fuel cycles.

2. Lattice cell calculations with LWRs.

The lattice cell of LWRs has a pin cell formed a square lattice as in figure 1. The geometry parameters are in table 1.

Parameters	Material (temprature)	PWR	BWR
R1(mm)	Fuel (900 K)	4.096	4.12
R2(mm)	Clad (600 K)	4.75	4.76
L(mm)	Water (600 K)	12.6	12.65



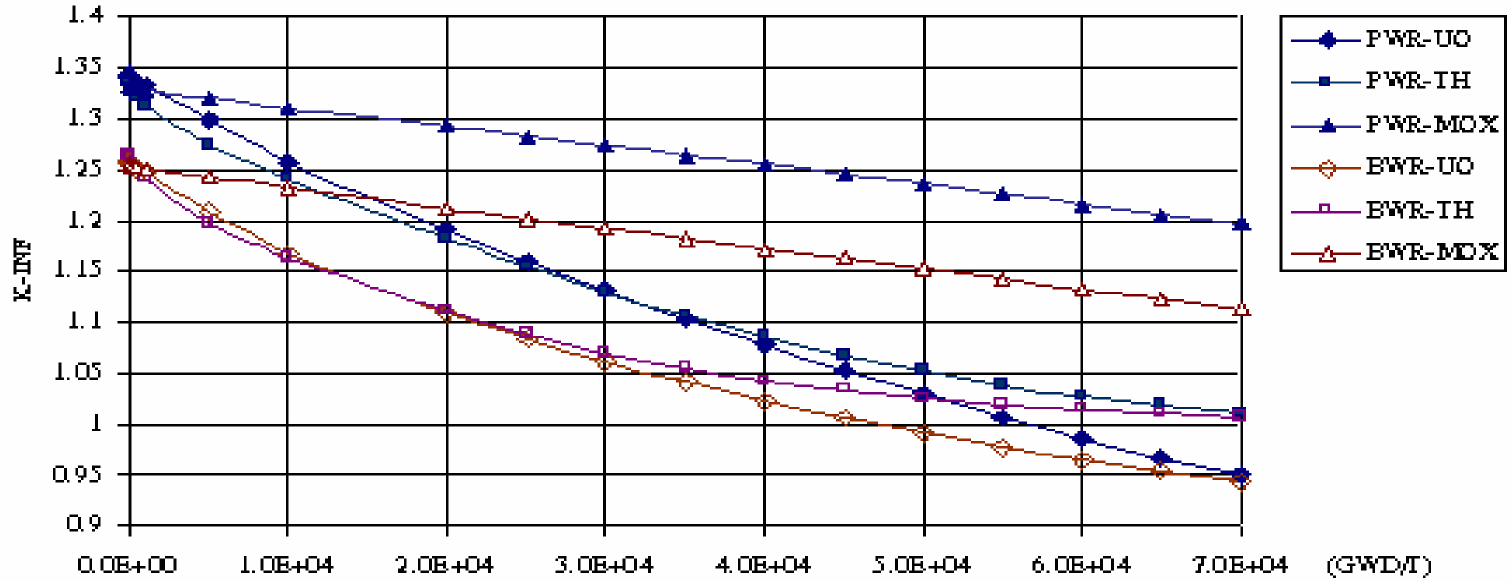


Figure 2: K-inf vs. fuel burnup

The variation of multiplication factor K-inf on fuel burnup is presented in figure 2. MOX and Th/U233 fuel can be burn up to 60GWd/T, while UO_2 fuel can be reach maximum at 35GWd/T – the average burnup of present LWRs.

3. Estimate of fuel conversion factor.

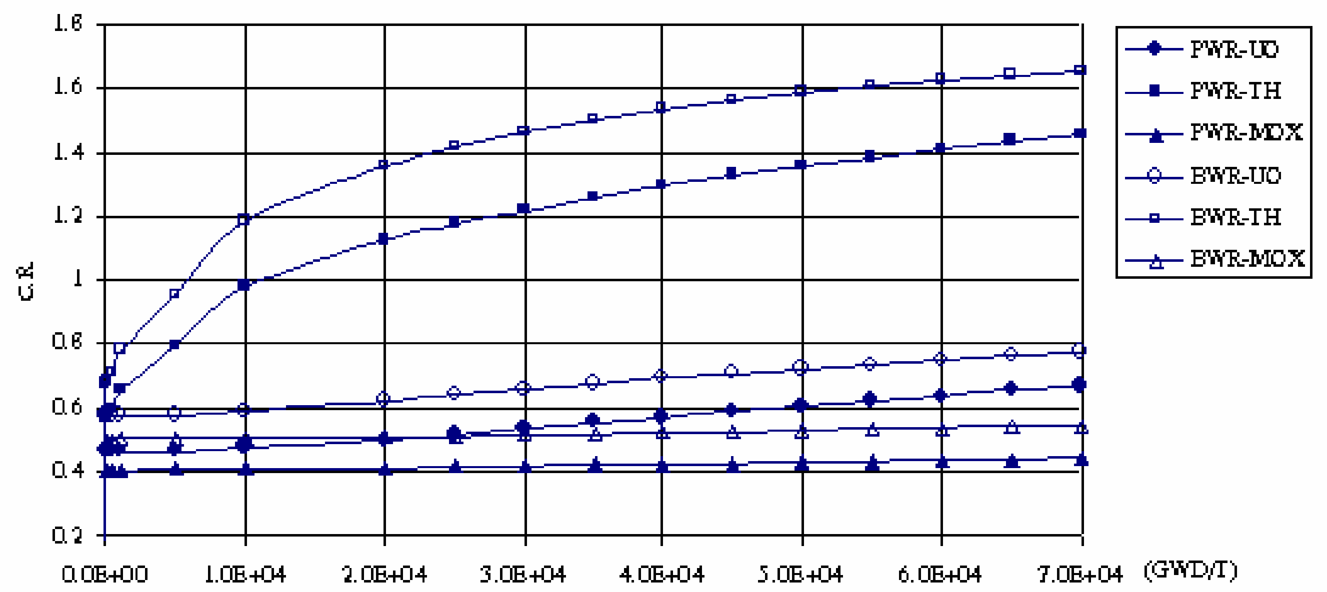


Figure 3: Conversion ratio (C.R) vs. burnup

- With UO2 and MOX fuels the conversion ratio is in the range of 0.5 to 0.7. Especially in MOX fuel, due to the main fission isotope is 239-Pu so that the conversion factor is not so high.
- while the 232-Th / 233-U fuel it is much higher as 233-U is breeded during fuel irradiation in the core, the value obviously is greater than 1. The figure 3 illustrates the variance of conversion factor by fuel burnup of three fuel cycles.

Table 2: 239-Pu content in the fuel burnup.

GWd/T	PWR			BWR		
	UO2	TH-U233	MOX	UO2	TH-U233	MOX
1.00E+02	3.73E-07	1.02E-09	6.74E-04	4.63E-07	1.10E-09	6.73E-04
5.00E+02	4.61E-06	1.35E-08	6.73E-04	5.70E-06	1.44E-08	6.73E-04
1.00E+03	1.06E-05	3.18E-08	6.72E-04	1.30E-05	3.38E-08	6.74E-04
5.00E+03	4.88E-05	1.54E-07	6.71E-04	5.97E-05	1.54E-07	6.80E-04
1.00E+04	8.20E-05	2.48E-07	6.65E-04	1.02E-04	2.29E-07	6.88E-04
2.00E+04	1.19E-04	3.23E-07	6.57E-04	1.55E-04	2.64E-07	7.01E-04
3.00E+04	1.39E-04	3.38E-07	6.34E-04	1.94E-04	2.45E-07	7.11E-04
4.00E+04	1.47E-04	3.65E-07	6.18E-04	2.20E-04	2.27E-07	7.19E-04
5.00E+04	1.50E-04	4.21E-07	6.01E-04	2.38E-04	2.19E-07	7.24E-04
6.00E+04	1.49E-04	5.02E-07	5.83E-04	2.51E-04	2.24E-07	7.27E-04
7.00E+04	1.47E-04	5.95E-07	5.65E-04	2.62E-04	2.44E-07	7.29E-04

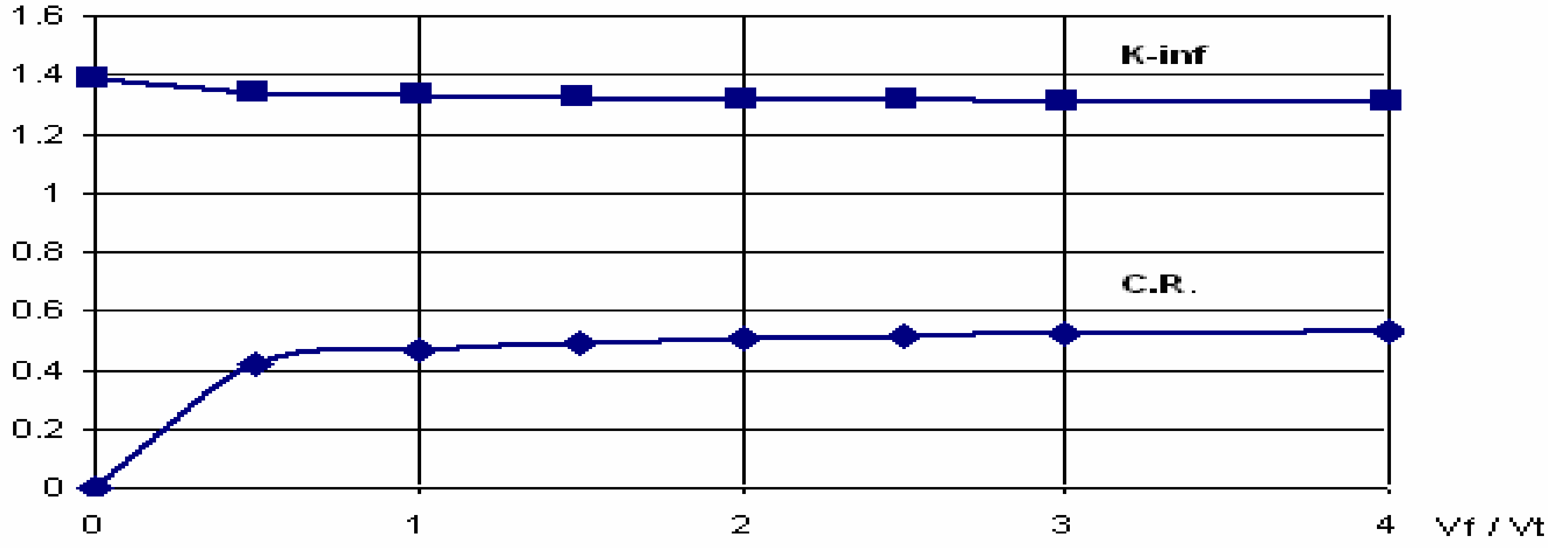


Figure 4: The multiplication factor K-inf and conversion ratio at burnup of 40 GWd/T vs. volume ratio of two-layer fuel rod.

The figure 4 represents the dependence of multiplication factor K-inf and conversion ratio at the burnup of 40 GWd/T by the volume ratio of UO_2 fuel alloy (VF) and Th/U233 fuel (VT). When the UO_2 volume increases, multiplication will be increased and conversion ratio decreases. However, these parameters will have minor change in the range 1.5 and 2.5 of the ratio VF/VT values.

4. Conclusion.

The Th/233-U fuel cycle with the important advantages:

- Contribute into burning of plutonium stockpiles, and 239-Pu produced by this fuel cycle is much less than MOX or UO2 fuel.
- High radioactive waste with large lifetime is less than other fuel cycles.
- High fuel burnup.
- Used for high temprature reactors (HTR).
- And sustainable as compare with limited uranium resource.

It will definitely be one of the remarkable options for nuclear fuel cycle in the future.

Thank you for your attention.