Neutronics Benchmark Development of the ALFRED Alike Reactor Using MCNP

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Introduction

A lead fast reactor (LFR) is a liquid metal cooled reactor that operates within the fast neutron spectrum. The Advanced LFR European Demonstrator (ALFRED) is a LFR design currently fostered by various European organizations [1]. ALFRED is rated 300 MW thermal power and is cooled by pure lead and operates in the temperature range 400 °C (core inlet) – 520 °C (average core outlet).

Methodology

For simplicity and thoroughness, the computational modeling process consists of three steps that break the whole core into three distinct levels that count for pin, subassembly, and full core configurations, respectively. Figure 1 illustrates the pin-level, subassembly-level, and supercell models of the LFR using the MCNP Visual Editor. Assessment with the LFR was performed with the 80 series data within MCNP 6.2 under the data set ENDF/B-VII.1 [2]. The desired dataset was one at 700 K, as this was the temperature for most of the materials used in the LFR benchmark model. To overcome this, we employed the stochastic mixing method. The idea of this method is using the data sets that bracket the value demanded in specific proportions to achieve the value needed. For example, the user would mix the 600 K and the 900 K data sets using interpolation to achieve the desired temperature.

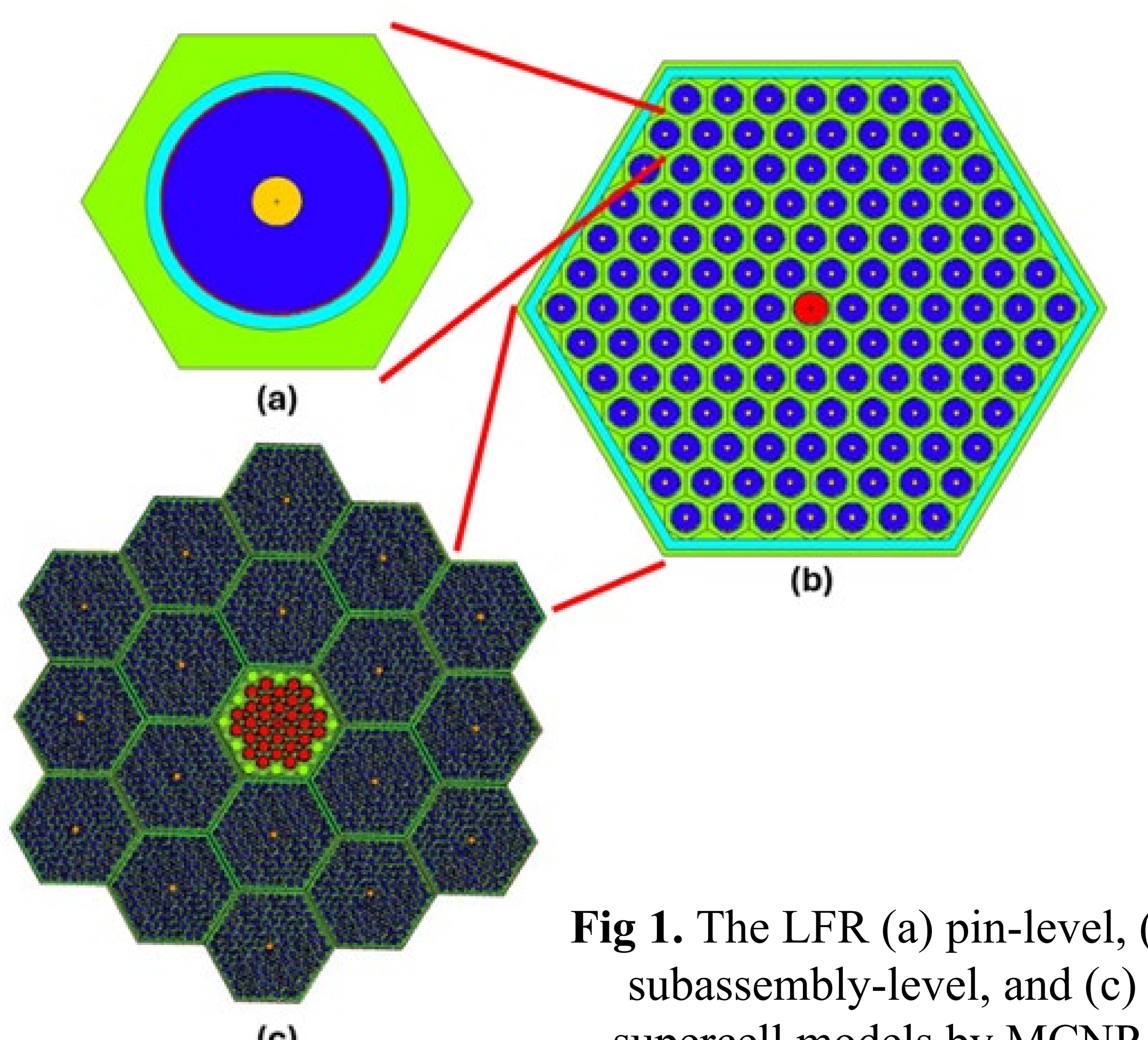

Fig 1. The LFR (a) pin-level, (b) subassembly-level, and (c) supercell models by MCNP.

Model Verification

As part of the verification efforts of the LFR benchmark development, results from the simplest level (the pin level) were compared to another independent working group's data. Results from the ININ (Instituto Nacional de Investigaciones Nucleares) were used for this comparison as their results were obtained using a different Monte Carlo based neutronics code – Serpent [3]. Table I summarizes these comparisons, and an overall good agreement is received between the results of both parties.

Table I. Pin Level Model Results Comparison.

Results from Inner Fuel Pin				
VCU		ININ		Difference
k_{eff}	Std Dev	k_{eff}	Std Dev	k_{eff}
1.34412	0.00005	1.34394	0.00002	0.00018
Results from Outer Fuel Pin				
VCU		ININ		Difference
k_{eff}	Std Dev	k_{eff}	Std Dev	k_{eff}
1.53004	0.00006	1.53025	0.00002	0.00021

Benchmark Results

The LFR calculation results are presented with three different subsections pertaining to the calculations that they hold. These subsections cover *k*-eigenvalue calculations (Table II), flux spectrum calculations (Figure 2), and burnup calculations (Figure 3), respectively.

Table II. Results of k_{eff} for the LFR Full Core at BOL.

Condition	k_{eff} (VCU)	k_{eff} (ININ)
Rod all out	1.00851±0.00009	1.00273±0.00002
CR inserted	0.96844±0.00009	0.95685±0.00002
Rod all in	0.95292±0.00011	-

Conclusions

A successful neutronics benchmark model has been established using MCNP for the LFR type of reactor analysis based on the ALFRED design. This reactor benchmark can be used for assessment and outlining certain properties of this reactor and its advantages. Some further work could include investigation onto reactivity coefficients and other fuel options.

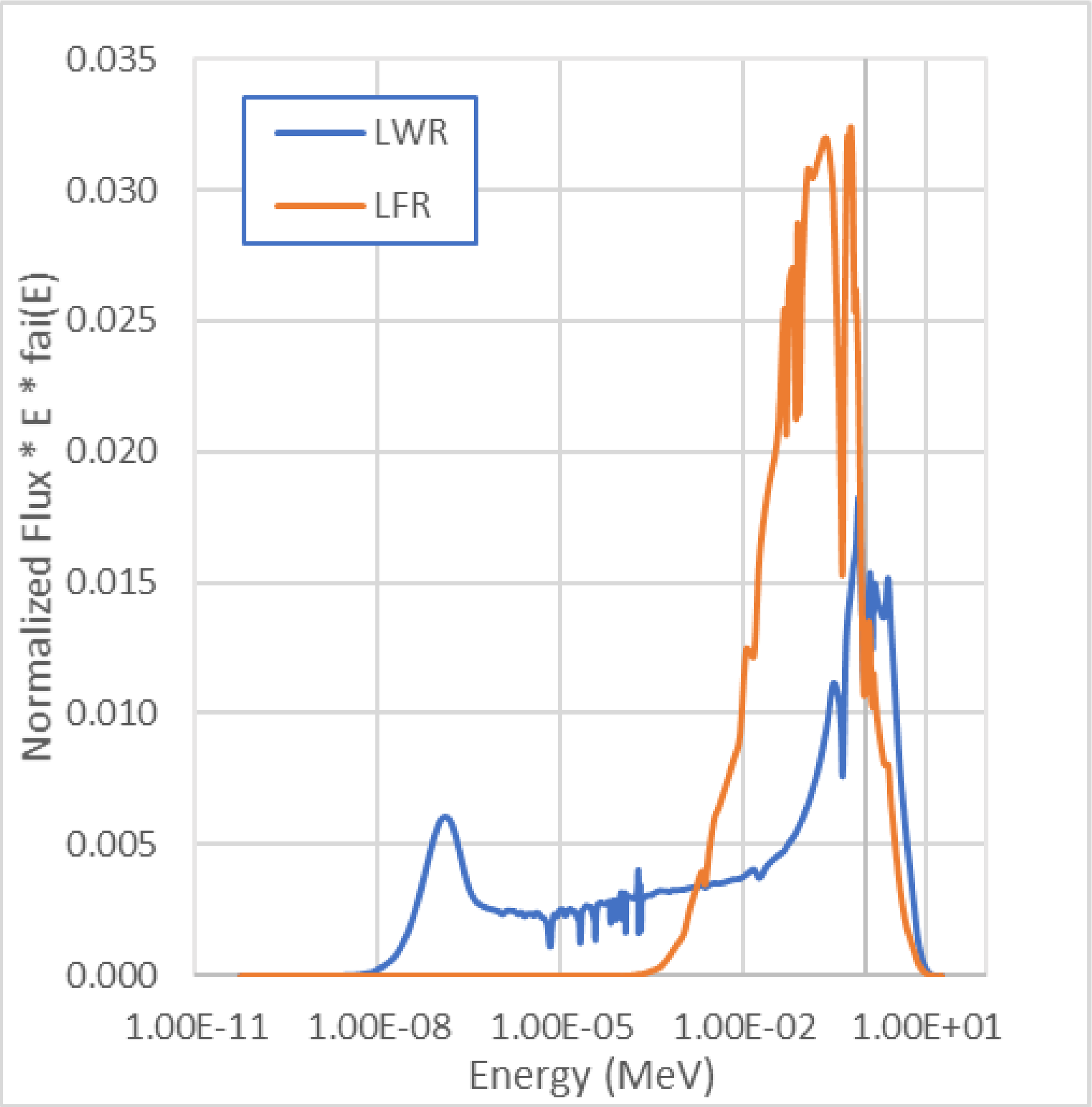

Fig 2. Flux spectrum comparison between a typical LWR and the LFR reactor.

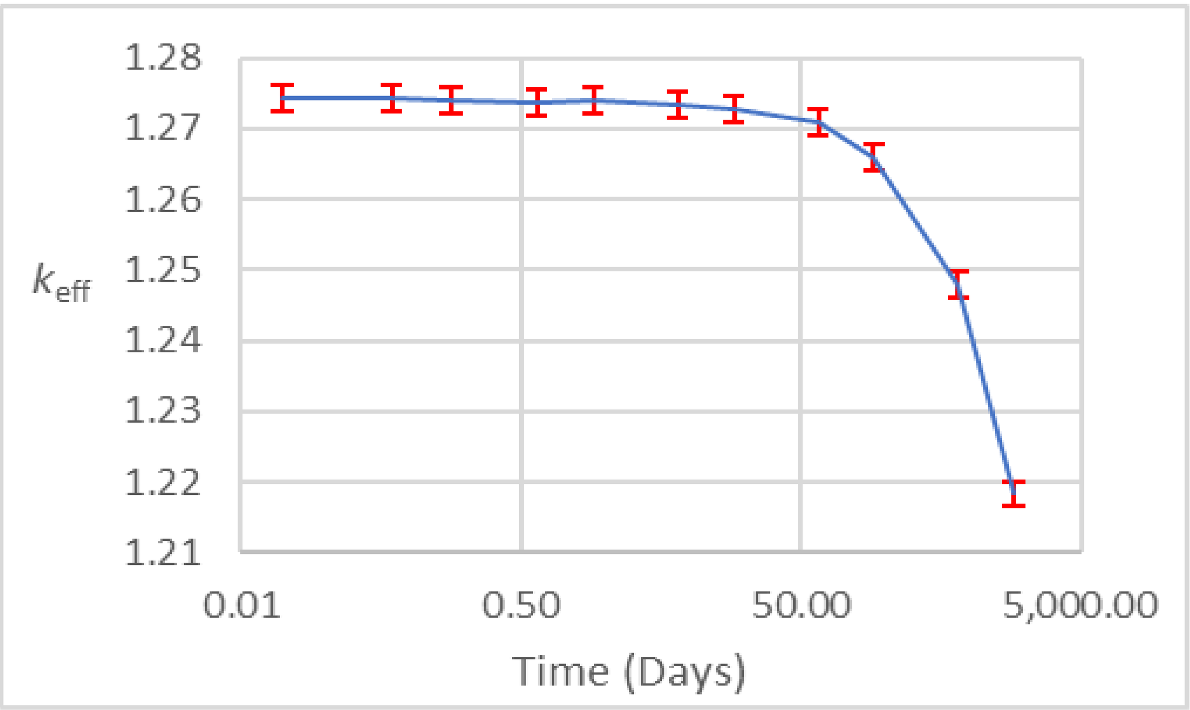

Fig 3. Subassembly k_{eff} as a function of burnup.

Acknowledgement

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References

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2. M. B. CHADWICK et al., "ENDF/B-VII.1 Nuclear Data for Science and Technology: Cross Sections, Covariances, Fission Product Yields and Decay Data," Nuclear Data Sheets, **112**(12), 2887-2996 (2011).
3. J. LEPPÄNEN, M. PUSA, T. VIITANEN, V. VALTAVIRTA, and T. KALTIAISENAHO, "The Serpent Monte Carlo Code: Status, Development and Applications in 2013," *Ann. Nuclei. Energy*, **82**, pp. 142-150 (2015)