STUDY ON THE CORRELATION OF NEUTRONIC AND THERMAL HYDRAULIC OF TRIGA MARK II PUSPATI REACTOR CORE

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ABSTRACT

In order to prepare Malaysia to be nuclear ready, the Malaysian 1 MW TRIGA MARK II research reactor (RTP) located at the Malaysian Nuclear Agency was premeditated with the aim to effectually actualize the multitude areas of basic nuclear research, labor training and education. To meet the modern safety standards, analyses of a strong interaction between the thermal-hydraulic system behavior and the space-dependent neutron kinetics are needed as mere thermal-hydraulics codes are said to be incapable to succeed the present safety standards. This could be achieved through the coupling of neutronic and thermal-hydraulic codes of the reactor. Previous studies had shown that the coupled codes are able to successfully be employed for the correlation between thermal-hydraulic analysis and neutron kinetics at transient and steady state. In this study, the coupling was achieved through MCNP and TRIGLAV codes for neutronic and thermal-hydraulic respectively. Core-15 of RTP was modeled for both of the codes; hence calculating the criticality, analysis of power and neutron flux distribution. The consistency and accuracy of the developed Core-15 MCNP model was established by comparing calculations to the experimental results and TRIGLAV code. The criticality predictions for both codes are in very good agreement with the experimental results. The core reached its criticality after 66 fuels. The highest hot rod power peaking factor was found to be 1.28. The results are conservative and can be applied to show the reliability of MCNP and TRIGLAV codes.

ABSTRAK

Dalam usaha untuk menyediakan negara Malaysia ke arah penggunaan tenagga nuclear, Malaysia mempunyai 1MW reaktor penyelidikan iaitu TRIGA MARK II yang terletak di Agensi Nuklear Malaysia. Tujuan reaktor ini adalah untuk penyelidikan asas berkaitan nuclear, latihan dan pendidikan. Bagi memenuhi piawaian keselematan yang ditetapkan, menganalisis interaksi antara tingkah laku sistem termal-hidraulik dan space-dependent neutron kinetics diperlukan sebagai satu kod. Kajian terdahulu telah menunjukkan bahawa kod ini berjaya dengan mengadakan hubung kait antara termal-hidraulik dan neutron kinetics at transient dan steady state. Dalam kajian ini, gandingan kod ini dicapai melalui penggunaan MCNP iaitu neutronic dan TRIGLAV kod iaitu termal hidraulik. Teras-15 RTP telah dimodelkan berdasarkan kod tersebut, lantaran itu, ia dapat menganalisis kritikal,

analisis kuasa dan neutron fluks. Konsistensi dan ketepatan model Teras-15 MCNP dibandingkan dengan hasil eksperimen kod TRIGLAV. Hasil kajian bagi kedua-dua kod ini dijangka sepadan dengan hasil eksperimen yang telah dijalankan. Teras-15 akan mencapai kritikal bagi penggunaan 66 bahan api. Hot rod power peaking factor yang tertinggi adalah pada nilai 1.28. Hasil keputusan ini boleh digunakan bagi menunjukkan keboleh percayaan MCNP dan TRIGLAV kod.

Keywords: thermal-hydraulic, neutron kinetics, neutronic, peaking factor, MCNP, TRIGLAV code

INTRODUCTION

Thermal-Neutronic calculation of nuclear reactor core, one of the necessary parts of nuclear power plant design; was calculated using numerical computer code. With their respective thermal flux characteristics, each fuel contributed to a total thermal neutron flux of core. Furthermore, safety prediction enhancements necessitated the complete revision of the whole power plant and demanded the adaptation of the method of investigation for each component, with multi-physics and multi-scales approaches[1]. The conversion of thermal neutron flux to the temperature of each fuel element of reactor core will determine the reactor power. In work, the analysis of thermal neutron flux for each fuel element and its associated power was conducted, focusing on the area surrounding each fuel element. The analysis was done by established analytical method and also with computer code MCNP and TRIGLAV.

EXPERIMENTAL

In order to accurately predict the reactor behavior under transient and accident conditions, researchers had been incorporating the coupling of thermal-hydraulic and neutronic codes and this had become a fundamental tool ever since. Using coupled codes, the problems and encounters relating to the precision and dependability of extrapolation in the transient analysis were able to be addressed.

The complete model of RTP was constructed using the MCNP5 code built on the 15th core configuration (see Figure 1) comprised of 114 fuel rods exactly placed along with suitable locations for 10 flux hole and 5 dummy fuel rods. For the simulation, the track length estimator of cell flux tally, F4 was chosen. This can be achieved by multiplying the particle weight to the track length in centimeters per surface volume in cubic centimeters.

TRIGLAV together with WIMSD use in order to compute a unit cell averaged cross section data. Furthermore, it can also be practical for fuel element burn up calculations, flux and power distributions and most importantly, for criticality forecasts [2].

Previous studies showed that a comprehensive range of code systems of the thermal-hydraulic plant modelling coupled with the 3D neutron-kinetic codes were advanced globally. These code frameworks turned out to be more practical and were utilized to accomplish analysis of accident set-ups compared to the method of the customary thermal-hydraulic scripting codes such as some of the reliable codes like RELAP5 with the neutron kinetics or replacing methods of the individual core models which are tedious since the boundary conditions needed to be delivered independently.
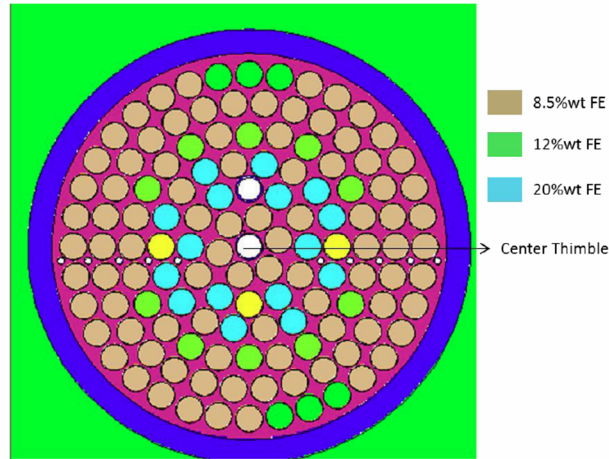
Figure 1: Fuel configuration for RTP Core-15[6].

RESULTS AND DISCUSSION

The k-eff obtained from MCNP for the 15th core configuration was 1.237 which was relatively higher compared to 1.05 from the measured k-eff obtained from previous study. There are a few possible explanations that could be addressed to this matter such that due to the limitation of MCNP as the fuel burnup or any temperature effect was neglected for the MCNP calculation. Moreover, it is also possible that there could be some error in the physical model or that it is because due to the simulation had to be stopped at 1206 cycles before it could complete its run at the supposedly 5000 cycles hence, affecting the average k-eff acquired.
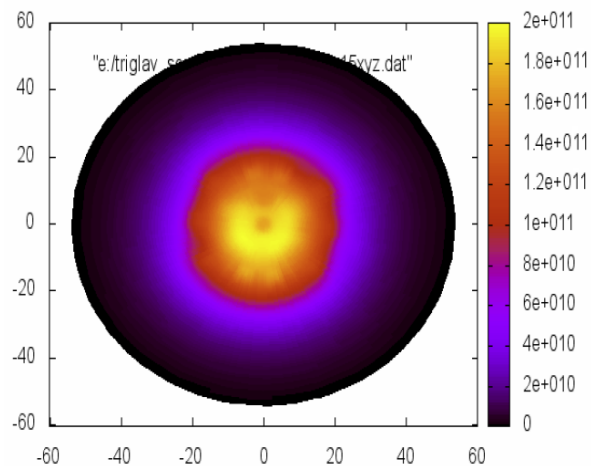

Figure 2: Flux distribution in Core-15 $(n.cm^{-2}.s^{-1})$.

The maximum neutron flux was anticipated to be circulated near the core center for any typical TRIGA reactor. From the Figure 2, we could observe that the area around the Central Thimble location has the highest thermal neutron flux similarly to what was anticipated. This is probably due because of the

thermalization of the fast neutron produced and the absorption of thermal neutron, consequently causing the increment of the thermal neutron flux in the aforementioned location as it is occupied with water moderator.
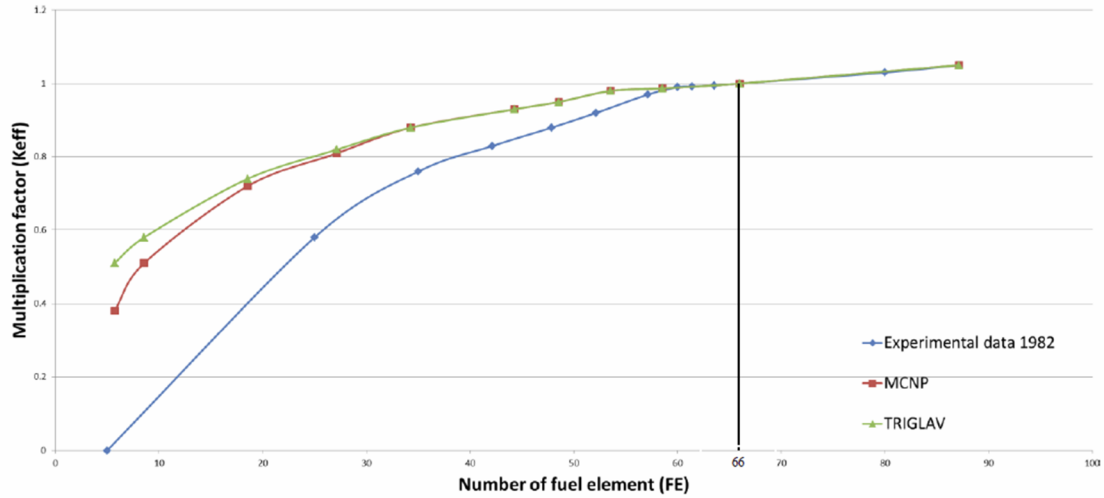

Figure 3: Approach to criticality curve [6].

The core reached its criticality at 66 numbers of fuels. Even though there is a great inconsistency in the subcritical region of the curve in the calculated results when comparing to the experimental results, the keff obtained from MCNP and TRIGLAV are still considered to be in an agreeable manner and considered able to verify both codes. Before the curve reached its critical state, we can observe that the curve of MCNP is closer to the experimental result compared to TRIGLAV. However, we can observe that in the supercritical region, all three curves become consistent, agreeing with each other as shown in Figure 3.
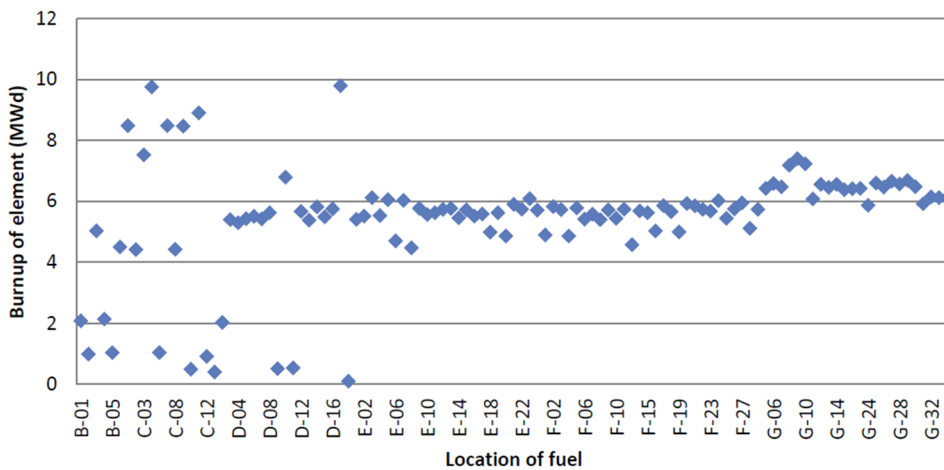

Figure 4: Fuel burnup of element based on their fuel location [6].

There are three types of fuel considered for fuel burnup which are ST8, ST12 and LEU. From Figure 4, we can observe that there is a large discrepancy from B-ring to D-ring. However, starting from E-ring, the burnup started to become consistent. There is also a slight increment in G-ring but it is still considered consistent. This is most probably because of the material of the fuels located from B-ring to D-ring are made up of fissile

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materials which are able to create fission, while non-fuel element such as graphite rods are not able to provide the fission power. Since the B-ring is the closest to the center core, the fast neutron produced caused inconsistency to the burnup power. On the contrary, the burnup became consistent as it moves out from the center core towards the reflector, around the G-ring region because of the thermal neutron was reflected back to the center by the reflector around that region.

Based on the Figure 5 for the value of the power for the location of fuel based on each ring, we can observe that the maximum power reached is located in E-ring with the power of 11.24kW. Therefore, by using equation 3.15, we found out that the highest hot rod peaking factor is 1.28.

$$fHR = (Prod)_{max} P_{core}$$

$$fHR = 11.24 \times 1031 \times 106114 \; fuels$$

$$fHR = 1.28$$

Where 1MW is the total power of RTP and 114 fuels is the number of element for Core-15.

Some locations in C-ring and also D-ring also have high value of power. This is because the E-ring contains 12%wt fuel types while for some location in C-ring and D-ring contain the 20%wt fuel types; hence causing the power peaking at these particular locations[6].
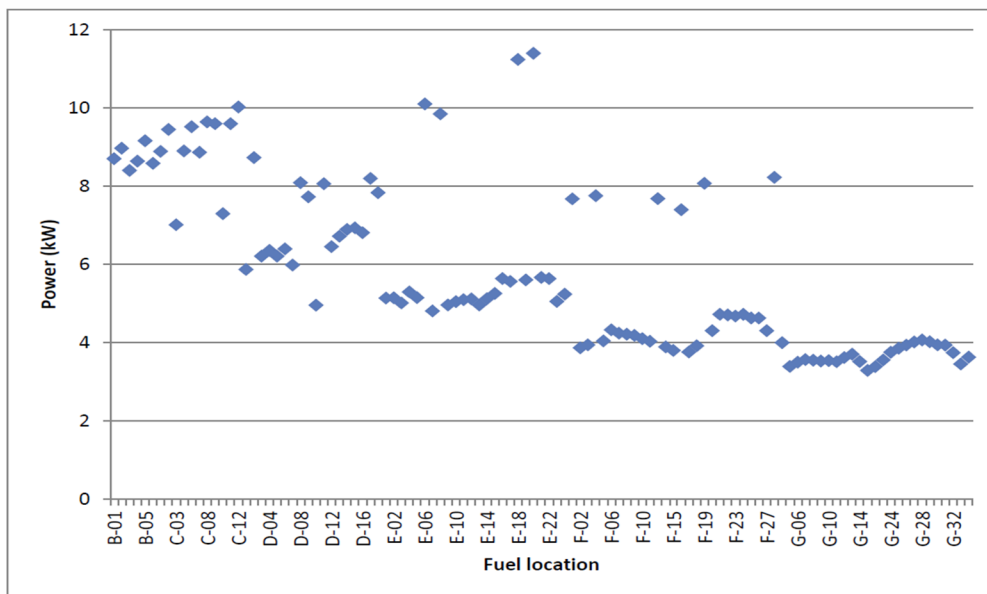

Figure 5: Power in kW of respective elements.

CONCLUSION

The modelling for the codes of MCNP and TRIGLAV were explained; hence from the output of those codes, the criticality and burnup were obtained. The 15th configuration was used. The output results from MCNP

and TRIGLAV were studied and were related with each other along with the as these regions comprises of 20%wt fuel types and 12%wt fuel types experimental data obtained from previous research back in 1982. The neutron flux was found to be the highest for the region near the core center of the reactor core. The core was found to reach criticality after 66 fuels and the reliability of all three outputs were verified. The burnup was also studied and it is found that the burnup power is not consistent near the center core due to fast neutrons. The power of the core was discovered to be the highest around C-ring, D-ring and E-ring.

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