Annals of Nuclear Energy 96 (2016) 96–103

Contents lists available at ScienceDirect

Annals of Nuclear Energy

journal homepage: www.elsevier.com/locate/anucene

Verification of MCNP6 model of the Jordan Research and Training Reactor (JRTR) for calculations of neutronic parameters

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A R T I C L E I N F O

Article history:
Received 28 February 2016
Received in revised form 28 May 2016
Accepted 1 June 2016

Keywords:
JRTR
Neutronic
K_{eff}
Criticality
Flux
Monte Carlo
Research reactor
Power peaking factor
MCNP6

A B S T R A C T

The Jordan Research and Training Reactor (JRTR) is a multi-purpose reactor with power of 5 MW currently under commissioning. The core consists of standard MTR plate type fuel assemblies with low enriched fuel of 19.75% U-235 enrichment. A new computational model has been developed for JRTR using the MCNP6 Monte Carlo code. The purpose of this paper is to validate the MCNP6 model by comparison of the calculation results of important neutronics parameters like k_{eff}, flux distribution, kinetics parameters, power peaking factors, and control rod worth to the reference results which were obtained by the McCARD Monte Carlo code and presented in the safety analysis report. Same modeling assumptions were adopted in the MCNP6 model in order to check the computational differences. In addition various up-to-date nuclear data libraries were used in calculations to assess their effect on calculated quantities. The calculation results showed good agreement and the difference in the effective multiplication factor is up 50 pcm.

1. Introduction

The Jordan Research and Training Reactor (JRTR) will be the first nuclear reactor in Jordan and will be mainly utilized for the purpose of training and education as well as radioisotope production. The JRTR is a multi-purpose open-tank-in-pool type reactor with nominal power of 5 MW upgradable to 10 MW. It uses low enriched (LEU) Uranium Silicide (U_3Si_2) as a fuel with enrichment of 19.75 wt%. The JRTR core consists of standard MTR plate-type fuel assemblies; each assembly is composed of 21 fuel plates. Each fuel plate is composed of a central fuel region – the fuel meat, surrounded by aluminum cladding. The fuel meat is made of fine and homogeneous dispersion of U_3Si_2 particles in a continuous aluminum matrix with a uranium density of 4.8 gU/cm^3 (Jaradat et al., 2015). The reactor core consists of 18 fuel assemblies which have the same U-235 enrichment and uses 4 different fuel densities for the initial core (Alawneh et al., 2014).

The JRTR has 4 control absorber rods (CARs) to control the reactor using Hafnium absorber, and 2 second shutdown rods for safe trip of the reactor using Boron Carbide. The reactor is light water moderated and cooled and reflected with two types of reflector, beryllium in the core region and heavy water in the region outside the core, as shown in Fig. 1. The fuel density distribution in the core is shown in Fig. 2. The JRTR has a central flux trap, 4 beam ports, a thermal column, and several irradiation holes in core and outside of the core which will be utilized in the future. The most important parameters of the reactor are given in Table 1 (JRTR-FSAR, 2014).

The design and calculation of the neutronic parameters of the JRTR were performed using Monte Carlo Calculation code McCARD for the initial, transition, and equilibrium cores at the beginning and end of each cycle (BOC, EOC). The McCARD code (Shim et al., 2012) is a Monte Carlo neutron and photon transport simulation code. It has been developed exclusively for the neutronics design of nuclear reactors and fissile systems. It is capable of performing full core neutronics calculations, reactor fuel burnup analysis, few-group diffusion theory constant generation, sensitivity and uncertainty analyses and uncertainty propagation analyses. It has some special features such as real variance estimation, neutronics analysis with temperature feedback, kinetics parameter calculation and Monte Carlo sensitivity and uncertainty analysis based on the use of adjoint flux.

The purpose of this work is to present the JRTR computational model in MCNP6 (Pelowitz et al., 2013) and validate it by

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http://dx.doi.org/10.1016/j.anucene.2016.06.003
0306-4549/

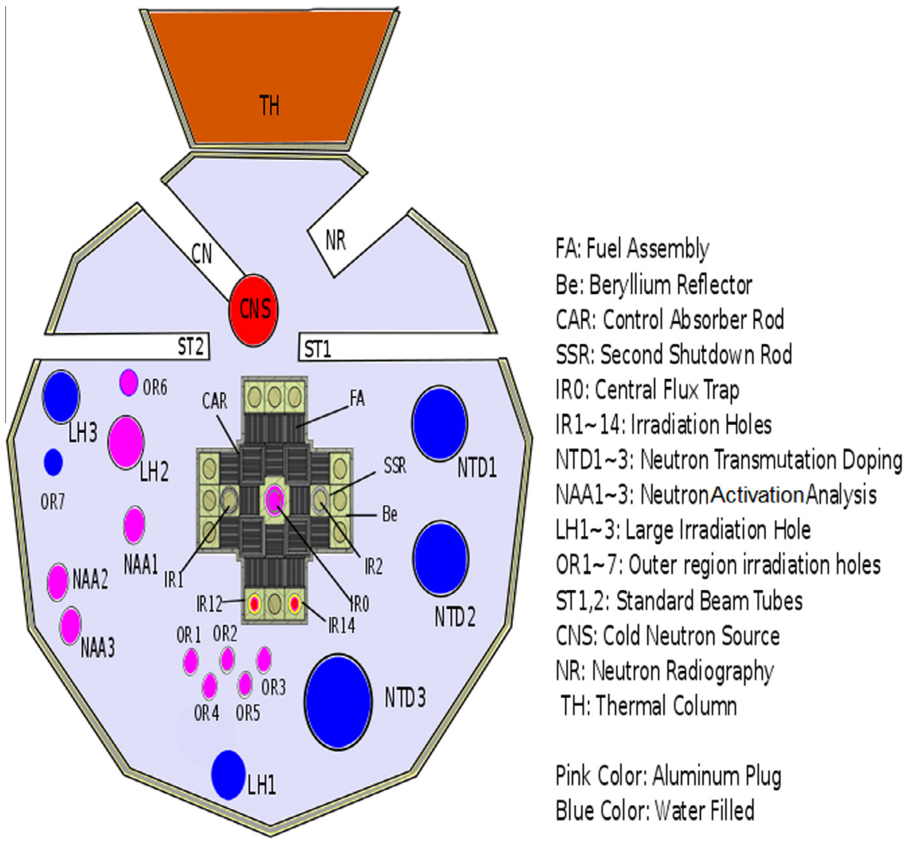

Fig. 1. JRTR core configuration top view with the irradiation positions.

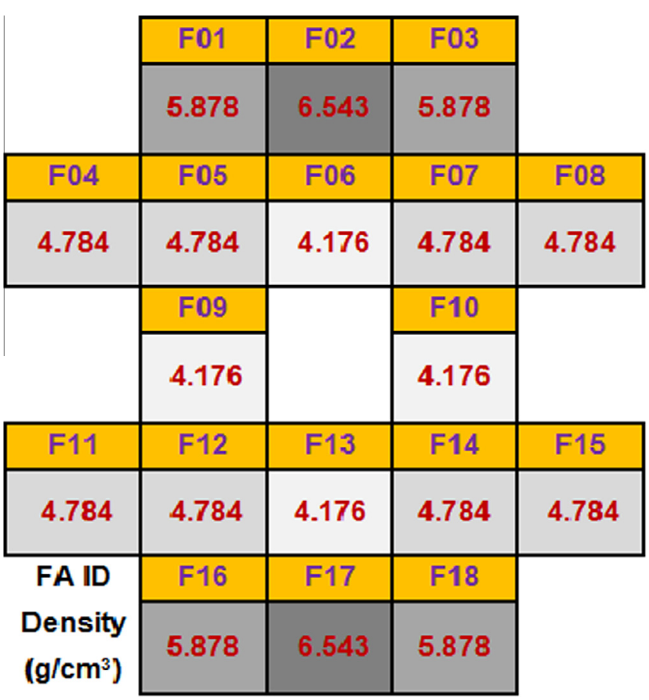

Fig. 2. JRTR initial core FAs distribution with different uranium/fuel densities.

comparing MCNP6 results with the reference results obtained by McCARD for the most important neutronic parameters of the core, i.e. k-eff, power peaking factors, kinetics parameters, control rod worths, neutron flux profiles. All calculations described in the paper are performed using the MCNP6 code which is a general-purpose, continuous-energy, generalized-geometry, time dependent, Monte Carlo radiation-transport code designed to track many particle types over broad ranges of energies. MCNP6 represents the culmination of a multi-year effort to merge the MCNP5 and MCNPX codes into a single code comprising all features of both. MCNP6 includes several significant new capabilities such as depletion,

Table 1
Major parameters of the JRTR core, fuel assembly and fuel plate.

Reactor core	Data
Number of fuel assembly sites	18
Number of irradiation sites in the Be reflector	12
Number of control absorber rods	4 (Hf)
Number of second shutdown rods	2 (B_4C)
Number of beam tubes	4
Reactor power	5 MW
Fuel meat, plate and assembly	**Data**
Fuel meat thickness	0.51 mm
Cladding thickness	0.38 mm
Fuel plate thickness	1.27 mm
Fuel plate width	70.7 mm
Fuel plate length	680 mm
Coolant channel thickness	2.35 mm
Number of fuel plate/Fuel assembly	21
Fuel assembly width	76.2 mm
Fuel assembly height	1015 mm
Material property	**Data**
Fuel meat	U_3Si_2–Al
Uranium density in fuel meat	4.8 gU/cm^3
Fuel meat density	6.543 g/cm^3
Cladding	Aluminum alloy
Cladding density	2.7 g/cm^3