Progress in Nuclear Energy 60 (2012) 27–30

Contents lists available at SciVerse ScienceDirect

Progress in Nuclear Energy

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

Implementation and benchmarking of ENDFVII based library for PBM reactor analysis with MCNP4c

Seyed Ali Hosseini [a,c,*], Mitra Athari Allaf [b]

[a] University of Tehran, Faculty of Science, Department of Physics, Tehran, Iran
[b] Islamic Azad University, Science and Research branch, Engineering Faculty, Nuclear Engineering Group, Iran
[c] Young Researchers club, Abhar Branch, Islamic Azad University, Abhar, Iran

ARTICLE INFO

Article history:
Received 30 January 2012
Received in revised form
6 May 2012
Accepted 6 May 2012

Keywords:
PBMR
HTR-10
MCNP4c
ENDFVII
ADS 2.0
Benchmark

ABSTRACT

Complexity in PBMR – Pebble Bed Modular Reactor – design has brought nuclear engineers to use Monte-Carlo based nuclear codes to analyze it. In this work we tried to improve the ability of the MCNP4c code in the analysis of such reactors. The improvement was reached through the updating of the cross-section library. Our main goal was to implement a new multi-temperature ENDFVII based library into MCNP4c and study its effects on PBM reactor analysis through the benchmarking process.

1. Introduction

In the early 70's a new reactor with innovative core design emerged. The fuel lumps were grouped inside fuel pebbles. According to the designers it had many advantages such as high burn-up rates and a high level of safety in comparison to classical PWR and BWR designs. The German research reactor based in Julich – the AVR – was the first reactor of this kind. The AVR shut down in 1988 due to contamination of the reactor vessel by Cs-137 and Sr-90. Nearly a decade after that, China's Tsinghua University began the construction of the HTR-10 reactor based on AVR's technology. It achieved its first criticality in 2003. In 2002 the IAEA proposed a set of neutronic benchmark (IAEA, 2003) problems as a way to verify the correctness and accuracy of different calculation methods and models. The unusual shape of the fuel and moderator is the main reason to the ineffectiveness of codes like WIMS and CITATION in the analysis of such reactors. Between different codes and versions of Monte-Carlo based neutronic analysis tools, MCNP4c (Briesmeister, 2000) is the most accessible. In a Monte-Carlo nuclear problem, the factors affecting the final result could be divided into these categories: geometrical modelling, accuracy of the input data – in this case the cross-sections – and the calculation process itself-parameters such as the NPS. In this paper only two of these categories will be discussed as the latter is not specific to PBM type reactors.

2. HTR-10 description

The HTR-10 is a 10 MW research reactor. The reactor core could be described as a cylinder connected to a cone at its lower end. The cone itself ends in a tube connected to the fuel management system. During operation, the core is filled up by spheres of 6 cm diameter (the word pebble is usually used). There are two types of pebble: fuel pebbles and moderator pebbles. Fuel pebbles have two regions; the first region contained inside a sphere of 5 cm diameter is called the fuel region. It has a graphite matrix with small particles inside called fuel particles. The second region, between the outer boundary of the fuel region and the pebble surface is solely composed of graphite and could be perceived as the moderator region.

Moderator pebbles, as suggested by their name are made of a moderating material: graphite.

The fuel particles, located in the fuel region of fuel pebbles are small spheres with 1.8 mm diameter. These particles are basically small amounts of 17% uranium oxide with 10.4 g cm^{-3} density

* Corresponding author. Young Researchers club, Abhar Branch, Islamic Azad University, Abhar, Iran.
E-mail address: hosseiniabhari@ut.ac.ir (S.A. Hosseini).

0149-1970/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.pnucene.2012.05.001

wrapped inside a special protective casing known as TRISO (IAEA, 2003). The TRISO casing is divided into 3 separate layers: an inner pyrolytic graphite layer and then a silicone-carbide and an outer pyrolytic graphite layer. The total mass of metal uranium per fuel pebble is equal to 5 g.

The standard ratio of fuel to moderator pebble inside the reactor core is 57 to 43. The walls of the reactor core are composed of graphite and borated graphite bricks.

The reactor has 10 control rods distributed around the core and located inside the graphite reflector. The control rods use (B_4C) as neutron absorber (IAEA, 2003).

3. ENDFVII library

ENDF library files, in their original format cannot be used with MCNP4c. The ENDF files have to be converted into point-wise continuous energy cross-section – also known as PENDF files. ENDF cross-sections are calculated for room temperatures, thus one should apply the Doppler broadening effect and other temperature related changes to the original file in order to be able to use them for higher temperature calculations (Cross-section evaluation working group, 2009). For our calculations, we used the ADS 2.0 library (Almada and Nichols, 2008) prepared by the IAEA using NJOY99. This library contains the cross-sections for 156 materials most of which are taken from ENDFVII. The cross-sections for 10 materials such as U-232 are taken from JENDL and IAEA-NDS project (Almada and Nichols, 2008). None of these materials were used in our calculations – all the cross-sections used were from ENDFVII. Another important factor is that the library contains cross-section data at 4 temperatures for all materials: 293.6 K, 600 K, 900 K and 1200 K.

4. MCNP4c modification

After the processing of the files in ace format and definition of the XS file we tried to run sample problems. During our tests we encountered an error while using the U-238 cross-section – not enough memory error.

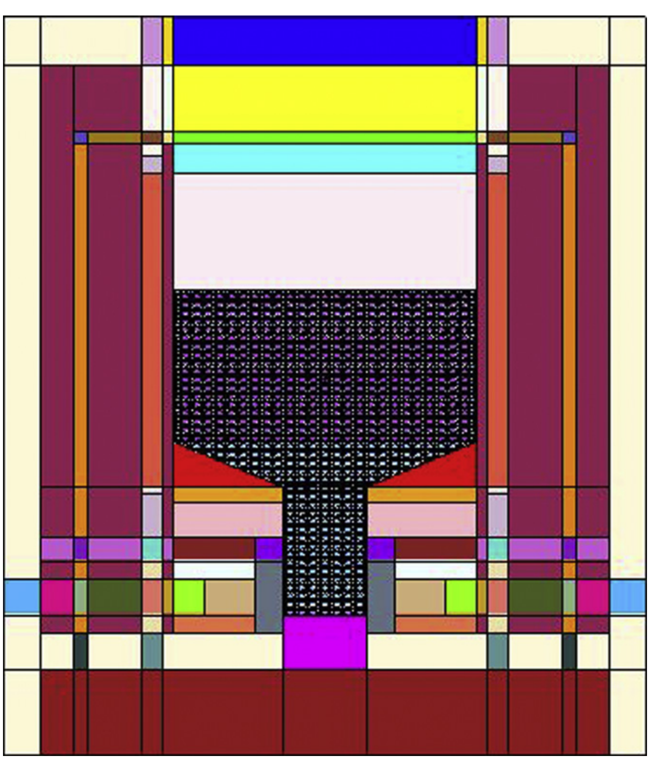

Fig. 1. Side view of the reactor core model.

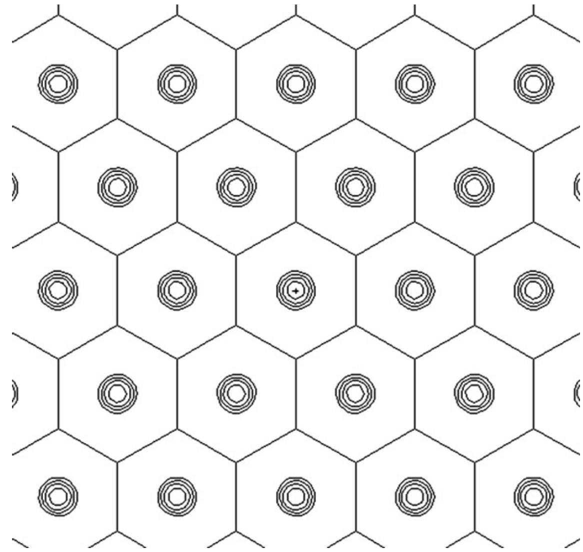

Fig. 2. View of an SC unit cell inside the fuel pebble.

MCNP4c uses a limited form of dynamically allocated storage (Briesmeister, 2000). Normally, the length and location of all arrays are defined during problem setup. The maximum length of these arrays is defined by the MDAS parameter (Briesmeister, 2000). One has the choice to define a constant value for MDAS or leave it up to the computer through dynamic memory size adjustment. The error was due to the fact that the *.exe file we were using was compiled with the first choice – predefined maximum array size.

5. Reactor core modelling

As mentioned earlier, MCNP4c has been used for the whole project. The reactor core geometry was taken from the CRP-5 report of the IAEA (IAEA, 2003). The reactor core model is shown in Fig. 1.

The main challenges during the modelling process are the followings: pebble and fuel particle modelling.

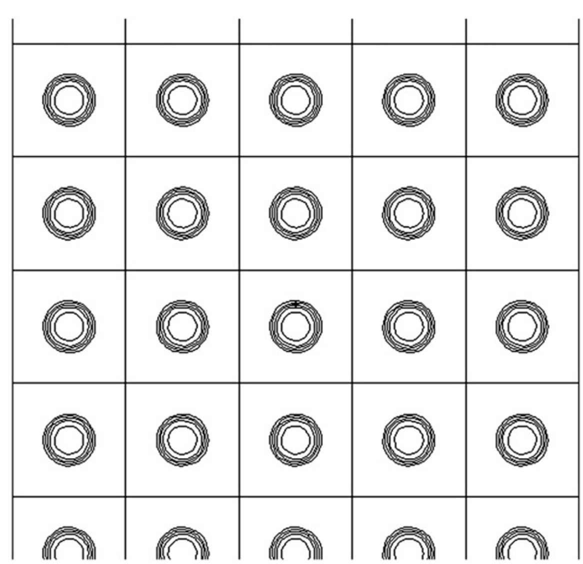

Fig. 3. View of an SH unit cell inside the fuel pebble.