UNIVERSAL APPROACH FOR ADS BLANKET CALCULATIONNS BY MONTE CARLO METHOD

Valeri V. Korobeinikov

Institute of Physics and Power Engineering
Bondarenko Sq.1, Obninsk, Kaluga Region, Russia
Fax: (7 - 095) 88 131 117 230 23 26
e-mail: korob@ippe.obninsk.ru

ABSTRACT

The universal scheme of Monte Carlo method has been developed for neutronic calculations of ADS blanket.

The new approach can be successfully used for calculations of ADS in a wide range of subcriticality levels. The theoretical substantiation and the results of test problem calculation are given.

I. INTROODUCTION

The interest in Accelerator Driven System (ADS) has grown rapidly in the last years. These systems offer solutions to several apparently problematic issues related to energy production in conventional fission reactors, such as

- Disposal of long lived actinides and fission products.
- Hazards involved in maintaining criticality margins.
- Exhausting supplies of uranium fuels.
- Proliferation of plutonium for weapons production.

In order to investigate scientific expectations the development of cods are demanded.

It is known that the efficiency of Monte Carlo calculation for subcritical systems with external source depends on subcriticality level. The lower subcriticality level the worse efficiency of Monte Carlo calculation.

The new scheme has been suggested for efficiency increasing of subcritical systems calculation. The efficiency of calculations by Monte Carlo method with new scheme does not depend on level of subcriticality.

II. THEORY

The main points of our approach are given below. The equation for neutron transport in a system with external source is:

$$\hat{L}\Phi(x) = \hat{B}\Phi(x) + Q(x), \qquad (1)$$

where:

$\hat{L}$ - neutron consumption operator (neutron absorption and leakage);

$\hat{B}$ - neutron production operator ,

Q - external neutron source.

The source multiplication factor is defined as:

$$M = \frac{\langle \hat{L}\Phi \rangle}{\langle Q \rangle}, \tag{2}$$

where $\langle ... \rangle$ means an integration over all variables. Many authors (see, for example, [1]) use instead of factor M another value which is defined as:

$$k_s = \frac{\langle \hat{B}\Phi \rangle}{\langle \hat{L}\Phi \rangle}. \tag{3}$$

Factor k_s is more convenient for subcritical system analysis. It is interpreted as the part of fission neutrons in all neutron balance of ADS blanket. k_s must be smaller than 1 for all subcritical systems with external source. Using (1) we may connect k_s and M:

$$M = \frac{1}{1-k_s} , \tag{4}$$

$$k_s = \frac{M-1}{M} . \tag{5}$$

At the same time for the system with fission materials can be defined the k_{eff} factor.

It should be noted that k_{eff} may be differed from k_s significantly. Really, for example, k_s depends on source position, source energy structure and so on. k_{eff} does not depend on source characteristics.

The calculation of subcritical system by Monte Carlo method is not .simple problem if k_s near one. To improve this situation the new scheme of calculation was developed and realized in the Monte Carlo code. The idea of our approach is based on a new formulation of Eq.(1). Using Eq.(3) Eq.(1) may be written in the form:

$$\hat{L}j = \hat{B}j + \frac{\langle \hat{B}j \rangle}{\langle Q \rangle} \frac{1-k_s}{k_s} Q . \tag{6}$$

Eq.(6) converts into Eq.(1) if φ=? , but Eq.(6) has another solutions too. All functions:

$$j\,(x) = \Phi(x) \cdot C\,, \tag{7}$$

where C – arbitrary constant are solutions of Eq.(6). Transform Eq.(6) into the next form:

$$\hat{L}j = \frac{\left\langle \hat{B}j \right\rangle}{k_s}\left[k_s \frac{\hat{B}j}{\left\langle \hat{B}j \right\rangle} + (1-k_s)\frac{Q}{\langle Q \rangle} \right] . \tag{8}$$

Since C is arbitrary constant we may choose it so that

$$\left\langle \hat{L}j \right\rangle = 1\,. \tag{9}$$

Using last equation we may write:

$$\hat{L}j = k_s \frac{\hat{B}j}{\left\langle \hat{B}j \right\rangle} + (1-k_s)\frac{Q}{\langle Q \rangle}\,. \tag{10}$$

The right part of Eq.(10) is the superposition of two normalized distribution. With probability k_s neutron is distributed on fission spectrum and with probability (1-k_s) neutron is distributed on external source spectrum. The last equation gives the way of the subcritical problem solving. This way is similar to the criticality problem solving.

The calculation procedure consists of two stages:

- Simulation of some preliminary generations to set up the initial distribution of fission neutrons.
- Simulation of basic generations. Estimations of flux functionals and k_s value.

The constant number N of neutrons is maintained in every generation. $k_s \cdot N$ fission neutrons are chosen from total N neutrons. $\left(1-k_s\right)\cdot N$ are the external source neutrons. So, the total number of neutrons is kept and equal N. The connection between f and F is very simple :

$$\Phi(x) = \frac{< Q >}{1-k_s} j\,(x) \tag{11}$$

Only light modifications of Monte Carlo Code MMKFK (k_{ef} option) was made for realization of this scheme.

III. NUMERICAL RESULTS

Results of k_s calculations for different source positions in ADS blanket are given on Fig.1. k_{ef} is given on Fig.1 too (for comparison). We see that statistic errors depend on k_s value very weakly. In case if k_s>1 the neutrons emit from fission source only and

subcritical problem transfers to quasicritical one. Instead of k_s value we get k_{ef} automatically.

IV. CONCLUSIONS.

- The new scheme for subcritical system calculation was developed.
- The new approach has been tested on ADS blanket model. The efficiency of new scheme depends on k_s (k_{ef}) value very weakly.
- The new approach is universal and transfers to quasicritical problem if k_s=1.

REFERENNCES.

1. I. Slessarev. “Accelerator Driven Systems (ADS) : A Principal neutronics and transmutation potential”. Accelerator Driven Systems: Energy Generation and Transmutation of Nuclear Waste. Status Report. IAEA. Vienna, 1997. IAEA-TECDOC-85.

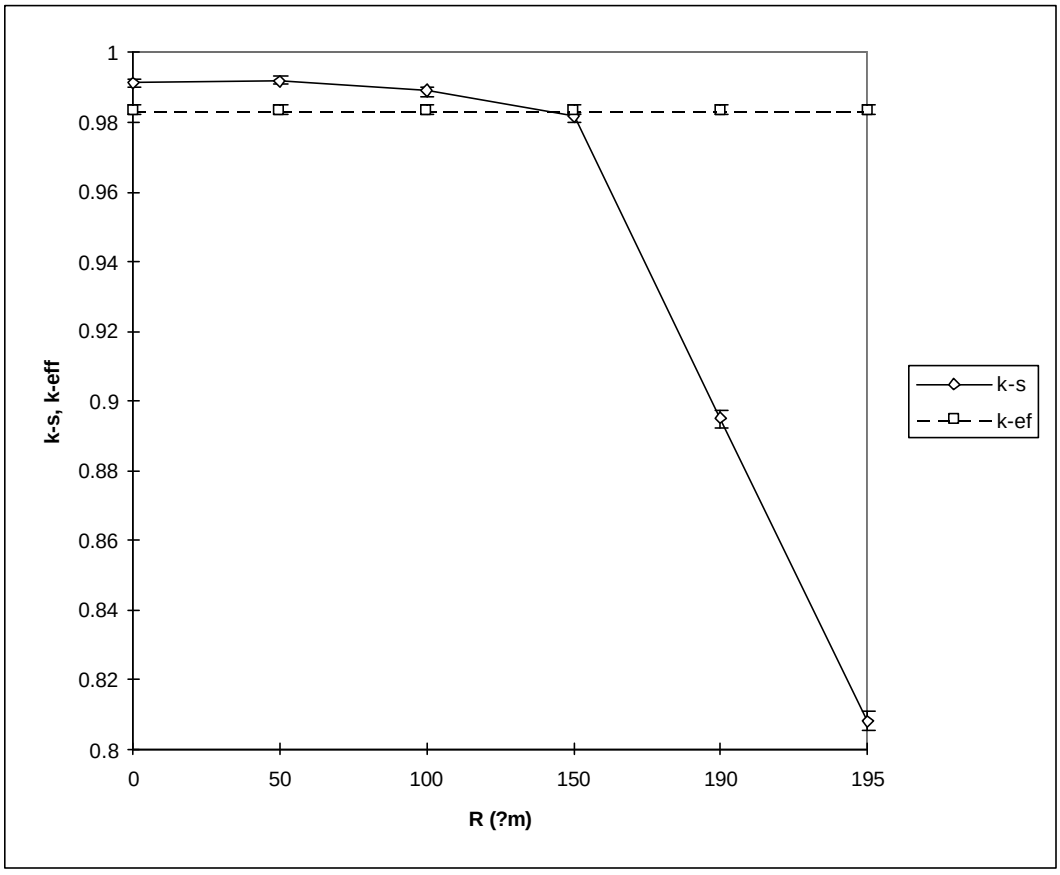

Fig.1. k_s as a function of source location.