Description of the basic scheme for coupled NK-TH calculations[1]

Jan Dufek
jandufek@kth.se
KTH, Stockholm

April 13, 2012

[1]To be implemented within the WP1 of the HPMC project.

Introduction

The included algorithms describe the basic coupling scheme for computing the steady-state coolant density distribution in nuclear systems. The identical algorithm can include a calculation of the steady-state distribution of any other quantity that depends on the power distribution and represents a reactivity feedback, such as the fuel temperature, distribution of ^{135}Xe, etc.

The included algorithms represent the basic scheme that has been originally described as the Optimal Process in Sec. IV.C. in [1]. For simplicity, the quantity d in [1] is set at 1, which is reasonable when the solution cannot be guessed to a known accuracy before the calculation.

This scheme increases the number of neutrons (cycles) simulated at each step to accelerate the convergence, and to lower the time needed to load the XS data by MC codes.

The following sections contain descriptions of two algorithms. They are identical. The second one is more suitable to work with when implementing in a script.

Declared quantities

The following quantities are declared:

i - the index of an iteration step of the coupling scheme,

s_i - number of neutron histories simulated by a Monte Carlo criticality code in ith iteration step,

S_i - combined number of neutron histories simulated in all iteration steps $1, \ldots, i$,

$\vec{\rho}^{(i)}$ - distribution of the coolant density computed according to relaxed power distribution $\vec{P}^{(i)}$ (see below),

$\vec{p}^{(i)}$ - power distribution computed by the MC criticality code in ith step

α - stepsize for the relaxation scheme,

$\vec{P}^{(i)}$ - relaxed power distribution, computed in ith step,

c_i - the number of active cycles (generations) simulated by the MC code at ith iteration step.

Values to be guessed

$\vec{\rho}^{(0)}$ - the initial distribution of coolant density has to be guessed (uniform distribution is OK),

b - neutron batchsize (I recommend to set the batchsize $b \leftarrow 500$ for the optimal convergence),

s_1 - the number of neutrons to be simulated in all cycles of the first iteration step needs to be guessed (choose this number so that the active cycles of the MC code run about a minute),

- initial fission source distribution at each iteration step must be guessed. It may not be the best idea to use the fission source from the previous iteration step. Try the uniform distribution; you may get better results.

- the number of inactive cycles in the MC calculation at each iteration step (I'd choose a few dozens of them)

Description of the coupling scheme

Algorithm 1 Basic scheme for coupled NK-TH calculations

input: s_1, b, $\vec{\rho}^{(0)}$
$S_0 \leftarrow 0$
for $i \leftarrow 1, 2, \ldots$ **do**
  $s_i \leftarrow (s_1 + \sqrt{s_1^2 + 4 s_1 S_{i-1}})/2$
  $c_i \leftarrow integer(s_i/b)$
  $\vec{p}^{(i)} \leftarrow$ power distribution in a system with coolant density $\vec{\rho}^{(i-1)}$
    distribution based on MC crit. simulation with c_i active cycles
  $S_i \leftarrow S_{i-1} + s_i$
  $\alpha_i = s_i/S_i$
  $\vec{P}^{(i)} \leftarrow (1 - \alpha_i)\vec{P}^{(i-1)} + \alpha_i \vec{p}^{(i)}$
  remormalize $\vec{P}^{(i)}$ so that the system gives required power
  $\vec{\rho}^{(i)} \leftarrow$ calculation of the steady-state coolant density distribution
    based on power distribution $\vec{P}^{(i)}$
end for

Algorithm 2 Basic scheme for coupled NK-TH calculations (as to be implemented in the script)

- **input:** s_1, b, $\vec{\rho}$
- **declare:** $S \leftarrow 0$
- **declare:** $\vec{P}$ (may be a zero vector)

for $i \leftarrow 1, 2, \ldots$ **do**

- **declare:** $s \leftarrow (s_1 + \sqrt{s_1^2 + 4 s_1 S})/2$
- **declare:** $c \leftarrow integer(s/b)$
- **declare:** $\vec{p} \leftarrow$ power distribution in a system with coolant density $\vec{\rho}$ distribution based on MC crit. simulation with c active cycles
- $S \leftarrow S + s$
- **declare:** $\alpha = s/S$
- $\vec{P} \leftarrow (1 - \alpha)\vec{P} + \alpha\vec{p}$
- remormalize $\vec{P}$ so that the system gives required power
- $\vec{\rho} \leftarrow$ calculation of the steady-state coolant density distribution based on power distribution $\vec{P}$

end for

Literature

1. Dufek, J. and Gudowski, W., "Stochastic Approximation for Monte Carlo Calculation of Steady-State Conditions in Thermal Reactors," *Nucl. Sci. Eng.*, Vol. 152, 2006, pp. 274.