A Look at Dynamic Fluctuations Following Control Rods Motion Using a Simplified Stochastic Reactor Kinetics Model

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1. Introduction

In a past study, a numerical investigation was conducted using the stochastic space-dependent kinetics model (SSKM, [1-2]) so as to observe the random oscillations in population dynamics following various transients regarding subcritical and supercritical reactors [3]. Nevertheless, the effect of control rods motion on these stochastic fluctuations has not been evaluated yet. Hence, the goal of this work is to give a look at the behavior of the dynamic oscillations subjected to sophisticated adjustments of control rods as the reactor is made supercritical by using the SSKM.

2. Methods and Results

In this section, a slab reactor is brought from a subcritical to a supercritical configuration in several manners of control rods motion in order to identify the resulting behavior of random dynamic fluctuations.

2.1 Investigation Method

The spatial model for a subcritical slab reactor is given in Table I with one effective delayed neutron precursor group. The system is made supercritical in several ways for inferring the trends in dynamic oscillations considering the speed and sequence of control rods withdrawal. The control rods motion is numerically modeled through changing the absorption rate by using the SSKM. Subsequently, the numerical results are characterized in terms of the mean value of neutron and precursor populations in Region i ($E(\bar{n}_i)$ and $E(\bar{c}_i)$), and in terms of the relative standard deviations in neutron and precursor populations in Region i (R_{SDNi} and R_{SDCi}), which are defined by the relations

$$R_{SDNi} = \frac{\sqrt{\overline{\left(\bar{n}_i - E(\bar{n}_i)\right)^2}}}{E(\bar{n}_i)} \text{ and}$$

$$R_{SDCi} = \frac{\sqrt{\overline{\left(\bar{c}_i - E(\bar{c}_i)\right)^2}}}{E(\bar{c}_i)}.$$

These quantities are actually measures of the relative dispersion in the neutron and precursor statistical distributions within the reactor system.

Table I: Spatial dependent model for a heterogeneous slab reactor (β = 0.0075, λ = 0.075, ν_p = 2.41, υ = 220000 cm/sec)

Kinetic parameters	Region 1	Region 2	Region 3
Fission rate $\upsilon\Sigma_{fi}$	1920/sec	770/sec	1920/sec
Absorption rate $\upsilon\Sigma_{ai}$	4670/sec	1870/sec	4670/sec
Slab thickness H_i	100cm	100cm	100cm
Diffusion coefficient D_i	0.15cm	0.09cm	0.15cm
External source S_i	500/sec	300/sec	500/sec
Initial conditions $[\bar{n}_i(0), \bar{c}_i(0)]$	[0,0]	[0,0]	[0,0]

2.2 Dependency on Speed of Rods Withdrawal

To examine the effect of control rods withdrawal speed on the asymptotic values of R_{SDNi} and R_{SDCi}, the reactor given in Table I is made supercritical in three different ways by linearly reducing the absorption rate in all regions at a rate of (a) 5/sec for the first 8 seconds, (b) 10/sec for the first 4 seconds and (c) 20/sec for the first 2 seconds. The dynamic variations are shown in Figs. 1, 2 and 3 for cases (a), (b) and (c), respectively.

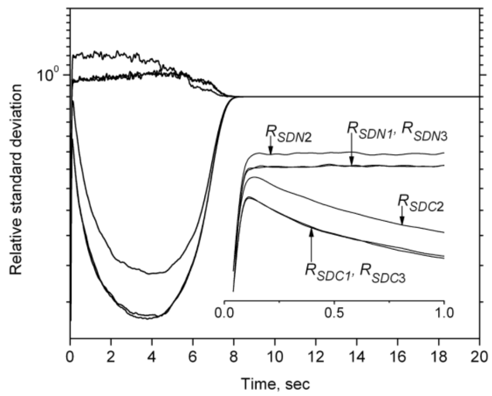

Fig. 1. Relative standard deviations in neutron and precursor distribution in a reactor which is brought from a subcritical to a supercritical configuration in case (a). The inset shows the high resolution of (0-1sec) range.

In accordance with the previous study [3], the same final nuclear properties are also obtained in Figs. 1-3 in which R_{SDNi} and R_{SDCi}, sooner or later, attain their asymptotic values that are identical in all regions as the reactor becomes supercritical, and $R_{SDNi} = R_{SDCi}$.

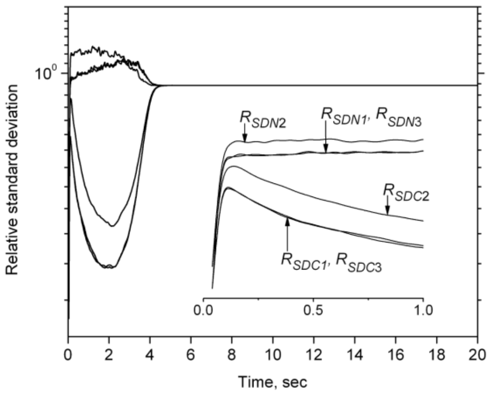

Fig. 2. Relative standard deviations in neutron and precursor distribution in a reactor which is brought from a subcritical to a supercritical configuration in case (b). The inset shows the high resolution of (0-1sec) range.

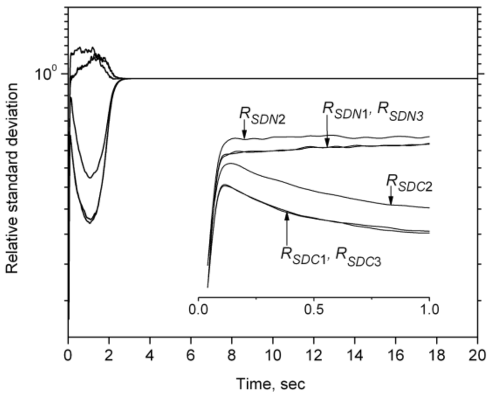

Fig. 3. Relative standard deviations in neutron and precursor distribution in a reactor which is brought from a subcritical to a supercritical configuration in case (c). The inset shows the high resolution of (0-1sec) range.

Accordingly, Figs. 1-3 indicate that the more rapid the withdrawal of control rods between fixed limits, the larger the asymptotic value of R_{SDNi} and R_{SDCi} (0.875 in Fig. 1, 0.928 in Fig. 2 and 0.971 in Fig. 3).

2.3 Dependency on Rods Withdrawal Sequence

In this case (d), the reactor given in Table I is made supercritical by linearly reducing the absorption rate in Region 1 at a rate of 10/sec for the first 4 seconds, then the absorption rates in Regions 2 and 3 are also linearly reduced at a rate of 10/sec from 4-8 sec. The results are exemplified in Fig. 4.

Fig. 4, in comparison with Fig. 2, signifies that when a number of control rods are to be withdrawn, each rod at the same rate, withdrawing the rods on one side of the reactor and then withdrawing the rods on the other side of the reactor results in a larger asymptotic value for R_{SDNi} and R_{SDCi} (1.184 in Fig. 4) than if all the rods are withdrawn simultaneously.

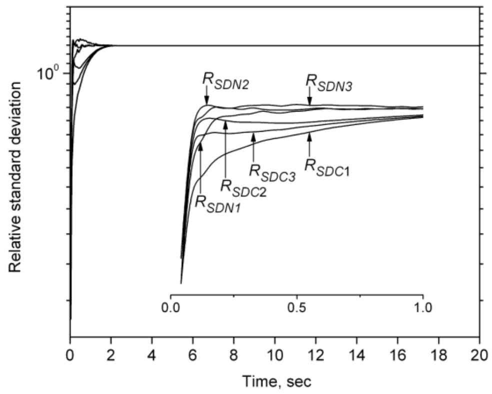

Fig. 4. Relative standard deviations in neutron and precursor distribution in a reactor which is brought from a subcritical to a supercritical configuration in case (d). The inset shows the high resolution of (0-1sec) range.

3. Conclusions

In this study, the behavior of dynamic fluctuations following control rods motion as the reactor is made supercritical was investigated numerically using the SSKM. The results show that the asymptotic value of the relative standard deviations in neutron and precursor distribution (R_{SDNi} and R_{SDCi}) in a supercritical reactor is sensitive to the manner in which the reactor is brought supercritical. Therefore, it is expected that the SSKM can be used for predicting the nature and characteristics of transients induced by control rods motion in space-time dependent reactor kinetics.

Acknowledgement

This study was supported by the Ministry of National Defense (2009-00000002197) and the Innovative Technology Center for Radiation Safety.

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