ON A GENERALIZED BIRTH AND DEATH MODEL APPLIED TO A POINT NUCLEAR REACTOR THEORY

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The operation of a nuclear reactor is caused, first of all, by the interaction of neutrons with a breeding medium - nuclear fuel. The course of these processes is determined by the neutron space-, energy- and time- distribution. The neutron distribution can be obtained by numerically solving the transport equation by substituting a complete set of reaction cross sections. This approach is widely described in the literature on nuclear reactors [1]. Obtaining such a solution is provided by Monte Carlo methods using computational codes and computer clusters. Capabilities of such methods are often limited only by solving homogeneous and stationary heterogeneous neutron transfer equations, which is sufficient to obtain results consistent with experiment. On the other hand, the methods and mathematical apparatus used in such codes are often hidden from the end user. This fact does not allow the user to track the calculation process and conduct its physical interpretation.

The approach proposed in current work is aimed at developing analytical methods for the analysis of nuclear reactor parameters. The approach is based on the general theory of probability mathematical apparatus. It was proposed to use a mathematical model of birth and death for this purpose [2, 3].

The model is based on the problem of the time-dependent process prediction. Prediction of values X_{n+r} in terms of $X_n, X_{n-1}, \ldots$ comes to the estimate of the quantity $[H(X_{n+r})|X_n, X_{n-1}, \ldots]$ for any function of interest H. According to the Chapman–Kolmogorov theorem [4] for Markov process, where X_n can be only countable, the following equation can be obtained:

$$E[H(X_n|X_m)] = E[E(H(X_n)|X_r)|X_m]. \tag{1}$$

Through the mathematical operations and inferences one can derive a simple solution for a Kolmogorov differential equations in application to the nuclear reactor. The main parameter to analysis in this case will be the average number of neutrons in the breeding medium of reactor core. The expression for estimating he average number of neutrons in a system is

$$\frac{M(t)}{dt} = [\lambda(t) - \mu(t)]M(t) + a(t) + b(t). \tag{2}$$

General solution for the Eq.(2) is well known. When the "breeding medium + neutron" system is being considered the more specific solution must be found taking into account parameters of the certain reactor core. Such a type of solution is shown in current work. Also the analytical equations for estimating main parameters of nuclear reactor (K_{eff}, ρ and etc.) were obtained from this solution.

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