Technical Journal, 7 (1980) 3 - 7

APPLICATION OF PULSED NEUTRON TECHNIQUE FOR NEUTRON FIRST COLLISION PROBABILITY STUDIES IN FINITE MEDIA

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ABSTRACT

A method used to determine neutron first collision probabilities in finite media has been given. Neutron first collision probabilities in finite cylindrical geometry water media having different radius and infinite height were determined. KAMAN A - 1001 model neutron generator was used as pulsed neutron source and a BF_3 detector was adopted to carry out time - dependent thermal neutron density distribution measurements. Neutron time decay in finite media has been explained on the basis of neutron first collision probability and following this interpretation, thermal neutron decay constants measured in the cylindrical geometry water media have been evaluated. Consequently, using the proposed method, neutron first collision probabilities were determined.

ÖZET

Sonlu ortamlarda nötron ilk çarpışma olasılığının ölçülmesine ait yeni bir yöntem verilmiştir. Yükseklikleri sonsuz kabul edilebilen, farklı çap değerlerindeki silindir geometrili su ortamlarda nötron ilk çarpışma olasılıkları ölçülmüştür. Deneyde, pulslu nötron kaynağı olarak KAMAN A - 1001 model nötron jeneratörü kullanılmıştır. Ortamdaki termik nötron yoğunluğunun zamana bağlı değişiminin incelenmesinde, BF_3 nötron dedektörü ile birlikte zaman analizörü kullanılmıştır. Sonlu ortamlarda termik nötronların zaman bozulması için nötron ilk çarpışma olasılığına bağlı bir yorum verilmiştir. Silindir geometrili su ortamlarında ölçülen termik nötron zaman bozulma sabitleri, söz konusu yoruma uygun olarak değerlendirilmiştir. Bu suretle sonsuz silindir geometrili su ortamlarda nötron ilk çarpışma olasılığı ölçülmüştür.

INTRODUCTION

Time - dependent thermal neutron studies have been widely performed by various authors [1 - 7]. The usual and well - known pulsed neutron technique has been used to measure thermal neutron decay constant in finite media. Diffusion approximation and diffusion - cooling modified diffusion approximation are applied to evaluate the neutron decay constant values. The last approximation was adopted for small geometries, however, for very small geometries no more success has been achieved for the

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explanation of decay constants. Application of a method about the medium-independent determination of thermal neutron time decay constant related with neutron first collision probability has been presented. There are quite a number of theoretical methods being applied to obtain neutron interaction probabilities in various media [8]. In this work, experimentally obtained decay constants were taken into consideration in order to calculate neutron first collision probabilities.

THEORY

Neutron mean free path in an infinite medium is given as $\lambda_{\infty} = 1/\Sigma$. On the other hand, the integration of the relationship for finite mean free path would yield,

$$\lambda = \lambda_{\infty} \cdot f_c \qquad (1)$$

where, f_c, defined as «geometric factor», is given approximately [9],

$$f_c = P_c - (\Sigma \bar{R}/2) \exp(-\Sigma \bar{R}/2) \qquad (2)$$

where, P_c is neutron first collision probability, Σ is total macroscopic cross section and $\bar{R}$ is so called «mean chord length» [10] which is given as $\bar{R} = 4V/S$ for a homogeneous neutron field.

Since diffusion coefficient depends on mean free path, comparing with Eq. 1, different definitions can also be obtained for this coefficient considering finite and infinite media.

Time-dependent neutron density distribution is given in an exponential form of $N = N_o \exp(-\alpha t)$ and from this, the relationship between neutron time decay constant, α, and the geometrical buckling, B_g^2 in diffusion approximation is,

$$\alpha = \alpha_o + D_o B_g^2 \qquad (3)$$

Here, the diffusion coefficient D_o was evaluated without considering the nature of medium [11]. However, it may be concluded that the term D_o in Eq. 3 is found for very large systems which are assumed as infinite. Therefore,

$$\alpha = \alpha_o + (D_o)_{\infty} \cdot B_g^2 \qquad (4)$$

can be written instead of Eq. 3.

The relation between diffusion coefficients for finite and infinite media is expressed as,

$$D_o = (D_o)_{\infty} \cdot f_c \qquad (5)$$

and inserting this into Eq. 3, the corrected thermal neutron time decay constant is found as :

$$\alpha = \alpha_o + (D_o)_{\infty} \cdot f_c \cdot B_g^2 (f_c) \qquad (6)$$

$\alpha(B^2)$ function is derived experimentally and from this diffusion parameters can easily be calculated. As a result, f_c and p_c values are obtained.

EXPERIMENT

$\alpha(B^2)$ curve was obtained employing the pulsed neutron technique. A KAMAN A-1001 model neutron generator operated in pulsed mode was used as pulsed neutron source and 14,7 MeV energy neutrons were produced by $H^3(d,n) He^4$ reaction. The thermal neutron density distribution was measured by a BF_3 neutron detector located in a constant position at the back of cylindrically shaped water media. The pipes filled with water having infinite height were close enough to target. Detector pulses were fed into ADC input of an Canberra 8100 multichannel analyzer through a Canberra Model 1406 preamplifier and a Canberra Model 1413 amplifier. The positive synchronized output of the pulse generator which was mainly used to supply different pulses with adjustable pulse repetition time and pulse width during pulsing operation was fed into «External Trigger» input of the MCA. Thus the analyzer was operated in MCSR mode giving the time dependence of thermal neutron density distribution.

Pulse width and pulse repetition rate were taken as 20 msecs and 3 mscs, respectively. In the case of large pulse width, background is increased and poor counting statistics was observed due to small pulse width. Optimized value for the pulse width was found as 20 msecs. The stopping period per channel was taken as 10 msecs and channel number was 256 in the MCA. Consequently the sweep of time decay of neutron density following a neutron burst between two subsequent neutron pulses in less than 3 msecs was made possible when the analyzer was operated in MCSR mode.

Four cylindirically shaped long pipes having different radius were used in the experiments. The time constants α of the decay of thermalized neutron field in water moderator were measured and correlated with the geometrical buckling B^2 of each system.

DATA EVALUATION, RESULTS AND DISCUSSION

The measured $\alpha(B^2)$ decay curves (Fig. 1) were used to calculate time constants with a computer programme. Background corrections were made within the programme. In diffusion-approximation, using a three-parameter least squares fit, diffusion parameters were calculated and the values for absorption constant, α_o, diffusion coefficient, D_o, and diffusion cooling coefficient C were found as follows :

$$\alpha_o = 4761 \text{ sec}^{-1}, \ (D_o)_\infty = 32422 \text{ cm}^2 \text{ sec}^{-1}, \ C = 8226 \text{ cm}^4 \text{ sec}^{-1}$$

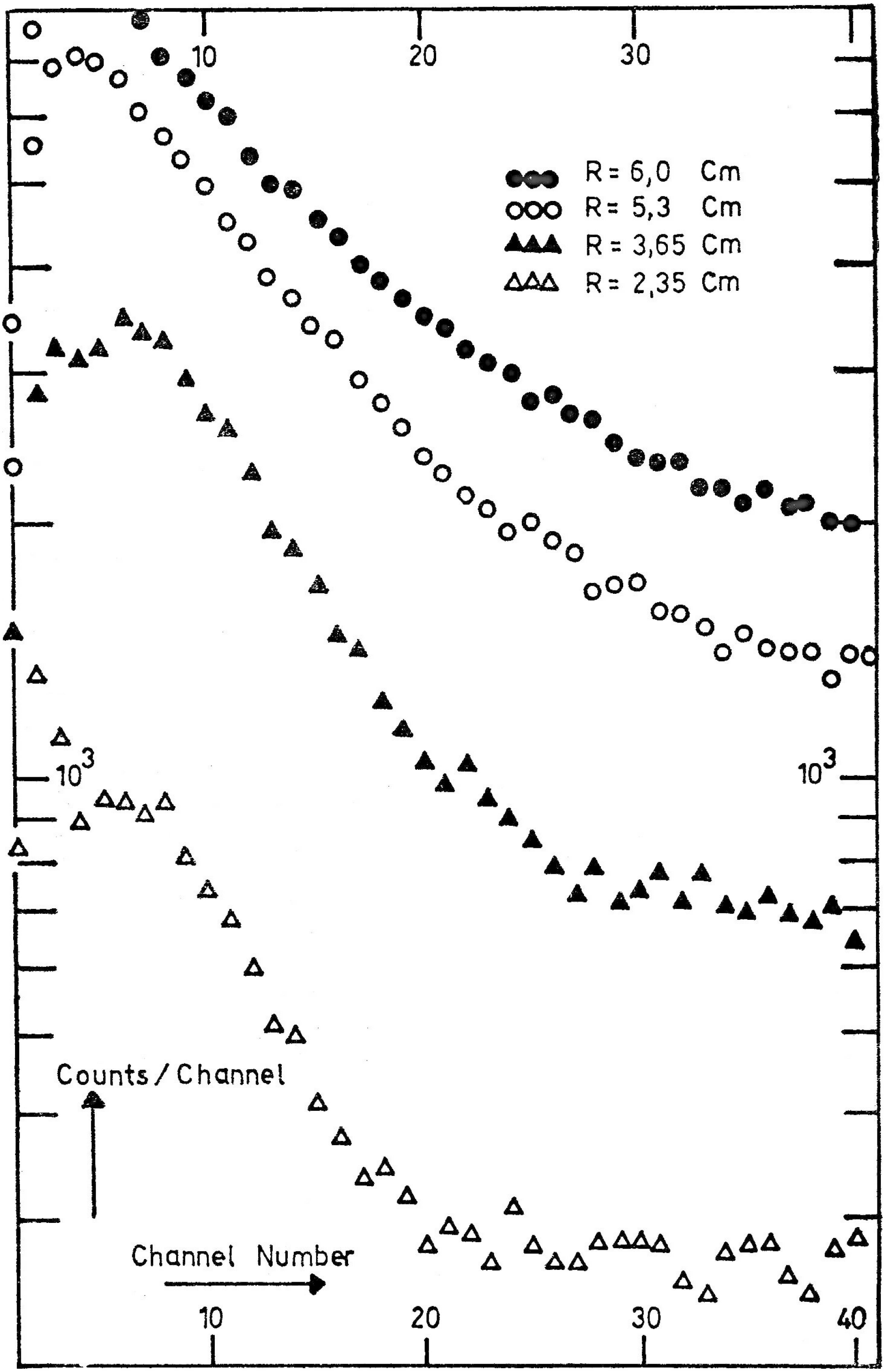

Fig. 1. Experimental decay curves in finite cylindirical water media.

As it was mentioned in the proposed method, first the geometric factor, f_c, was calculated from Eq. 6 using an iteration programme based on the «Regula Falsi» method and then to calculate P_c values, in the case of infinite cylindirical geometry, the following equation derived from Eq. (2) was used :

$$P_c = f_c + R\,\Sigma \exp(-R\Sigma) \tag{7}$$

Measured α values and the calculated f_c, P_c values were given in Table — 1. These P_c values were found quite less than those calculated by Case et. al., [8] using the «Bath Method», due to the different physical conditions. In Case's work, first collision probability for the neutrons from a homogeneous source injected into a medium was calculated, but, in this work, source neutrons produced in the medium were considered.

TABLE — 1. Experimental results and calculated f_c, p_c values

R (cm)	B^2 (cm^{-2})	α (exp.)	f_c	p_c
6.00	0.1454	9379	0.976562	0.976563
5.30	0.1840	10348	0.927734	0.927735
3.65	0.3695	15642	0.893555	0.893595
2.35	0.8197	25803	0.747070	0.749439

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