

Journal of Nuclear Science and Technology

ISSN: 0022-3131 (Print) 1881-1248 (Online) Journal homepage: www.tandfonline.com/journals/tnst20

On Source-Transient Region of Neutron Waves in Multiplying Systems

Takaaki MATSUMOTO

To cite this article: Takaaki MATSUMOTO (1970) On Source-Transient Region of Neutron Waves in Multiplying Systems, Journal of Nuclear Science and Technology, 7:9, 474-476, DOI: 10.1080/18811248.1970.9734722

To link to this article: https://doi.org/10.1080/18811248.1970.9734722

Published online: 15 Mar 2012.

Submit your article to this journal

Article views: 191

View related articles

Full Terms & Conditions of access and use can be found at
https://www.tandfonline.com/action/journalInformation?journalCode=tnst20

Journal of NUCLEAR SCIENCE and TECHNOLOGY, 7[9], p. 474~476 (September 1970).

SHORT NOTE

On Source-Transient Region of Neutron Waves in Multiplying Systems

Takaaki MATSUMOTO*

Received February 21, 1970

A recent development in reactor physics has been the application of the neutron-wave propagation technique to multiplying systems, and determination of 'dispersion laws' for neutron waves in several systems[1]~[3]. The dispersion law in a system is usually obtained from measurements in an asymptotic region far away from the source and from the surfaces. The asymptotic energy spectrum in a multiplying system is generally different from the thermal spectrum of the source, and thus the source-transient region will occupy a fairly wide region in the system. This note covers a study of the source-transient region for obtaining exact dispersion laws in multiplying systems.

As a general rule, thermal neutrons that have undergone some kind of interaction with the medium only a few times predominate in the source-transient region. As the frequency of such interactions decreases and on the other hand as the effects of the interactions on the neutron waves are stronger, the transient region in the system will become wider. In the case of a multiplying system with a small multiplicity and a large age of thermal neutrons, the frequency of the fission process is low for most of the neutrons. The succeeding slowing-down process greatly affects the neutron waves because of the strong penetration and the high velocity of the fast neutron. The system will have a wide source-transient region in which most of the neutrons will have undergone fission only a few times.

We will analyze the source-transient region depending on the number of fission processes undergone by the neutrons. The thermal neutron wave $\phi(\boldsymbol{x}, \omega)$ in the system can be classified into a series of partial waves $\phi^{(n)}(\boldsymbol{x}, \omega)$ according to the number n of fission processes experienced:

$$\phi(\boldsymbol{x}, \omega)=\sum_{n=0}^{\infty}\phi^{(n)}(\boldsymbol{x}, \omega), \quad \text{for } n=0, 1, \cdots, \quad (1)$$

where ω is the angular frequency of the modulated source. Equation (1) always converges in a subcritical system and will converge fast in the source-transient region predominated by components of small n.

Let us now consider the simple case of perpendicular propagation in a plane-lattice system of moderator and fuel plates — a case lending itself well to application of the cell-model. This will not restrict the generality of the results, because for propagation parallel to the plane- or rod-lattices the equations presented below would require only slight modification such as replacement of the summations by integrations.

The neutron flux in the moderator region is described by a time-dependent, one group diffusion equation. Hence the fundamental equations for the wave component with an (l, m) mode for the transverse distribution can be obtained in the usual manner:

$$D\frac{d^2}{dx^2}\phi_{lm}^{(0)}(x, \omega)-\left(\Sigma_a+DB_{\perp lm}^2+j\frac{\omega}{v}\right)\phi_{lm}^{(0)}(x, \omega)+\delta(x)S_{lm}(\omega)=0 \quad (2)$$

and

$$D\frac{d^2}{dx^2}\phi_{lm}^{(n)}(x, \omega)-\left(\Sigma_a+DB_{\perp lm}^2+j\frac{\omega}{v}\right)\phi_{lm}^{(n)}(x, \omega)+\lambda\sum_k q_{lm}(x_k\to x;\ \omega)\phi_{lm}^{(n-1)}(x_k, \omega)=0, \quad \text{for } n=1, 2, \cdots \text{ and } l, m=0, 1, \cdots, \quad (3)$$

where $\lambda=p\nu\Sigma_f T/\zeta$

T: Thickness of fuel plate
ζ: Disadvantage factor
k: Index number of fuel plate.

If the age model is used for calculating the slowing-down density $q(x_k\to x;\ \omega)$, the solutions with the (l, m) mode become:

$$\phi_{lm}^{(0)}(x, \omega)=c_{lm}\exp(-\rho_{lm}x) \quad (4)$$

and

$$\phi_{lm}^{(n)}(x, \omega)=\lambda\sum_k G_{lm}(x_k\to x;\ \omega)\phi_{lm}^{(n-1)}(x_k, \omega), \quad (5)$$

* Research Reactor Institute, Kyoto University, *Kumatori-cho, Osaka.*

where $\rho_{lm}=\sqrt{\Sigma_a/D+B^2_{1lm}+j\omega/(vD)}$

(hypothetical dispersion law in system with $\nu=0$)

$$G_{lm}(x_k\to x;\ \omega)=\exp(-B^2_{1lm}\tau-j\omega l_s)\cdot\int_{-\infty}^{\infty}dx'\,\frac{\exp(-\rho_{lm}|x'-x|)}{2D\rho_{lm}}\cdot\frac{\exp\{-(x'-x_k)^2/4\tau\}}{\sqrt{4\pi\tau}}$$

τ: Fermi age of thermal neutrons from fission energy

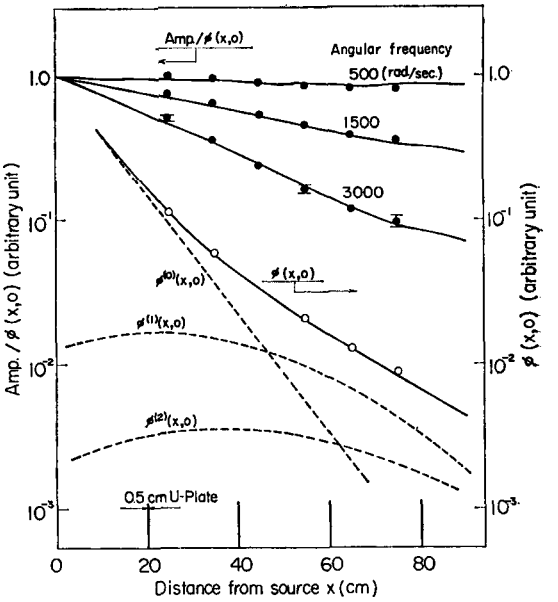
l_s: Slowing-down time from fission to thermal energy

c_{lm}: Coefficient determined by source condition.

Experiments on perpendicular propagation were carried out in a plane-lattice system with a small multiplicity and a large age of thermal neutrons. The system consists of a graphite moderator with transverse dimensions $100\times100\,cm^2$ and with four sheets of 0.5 cm thick natural uranium plates placed in graphite with a lattice spacing of 20 cm. The overall length of the system is about 100 cm. A sinusoidally modulated point source of thermal neutrons[4] was used on this system. The measured amplitude and phase lag are shown in **Figs. 1** and **2**, respectively. For $\omega\leqslant3{,}000$ rad/sec, the amplitude is seen to be nearly exponential, whereas the phase lag is not linear. This indicates that in this experiment no asymptotic distribution is yet reached at a distance of about 50 cm from the source.

Using the fission expansion method mentioned earlier, the total waves $\phi(x,\omega)$ were calculated from Eq. (1) and the partial waves $\phi^{(n)}(x,\omega)$ from Eqs. (4) and (5). Examples of the results obtained for the fundamental spatial mode ($l=m=0$) are presented in Figs. 1 and 2. The calculations for $\phi(x,\omega)$ converged within 1% using only 5 terms in Eq. (1), and are in good agreement with experimental results.

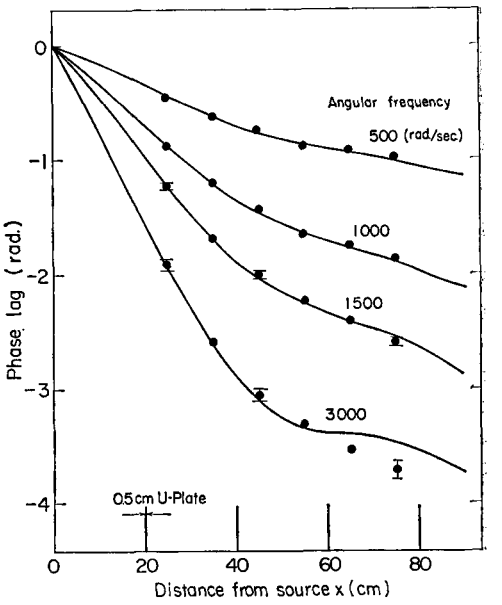
From these calculations and experiments, it is concluded that in a low-multiplying system, there exists a wide source-transient region in which most of the neutrons have undergone fission only a few times. Decreasing multiplicity of the system and increasing age of the thermal neutrons will widen the transient region. Similarly, a wide transient region would appear with propagation in other directions and lattice geometries. The exact dispersion law cannot be derived from



●, ○: Experiment

——, - - -: Fission expansion calculation based on age-diffusion theory

Fig. 1 Distributions of amplitude



●, ◐: Experiment

——: Fissicn expansion calculation based on age-diffusion theory

Fig. 2 Distributions of phase lag

the measurements in regions where the energy spectrum deviates appreciably from its asymptotic configuration for the system. This means that in a longer system it would be necessary to carry out measurements farther away from the source.

It can be also expected from the present analysis that a modified source having a spectrum closely akin to the asymptotic form for the measured system will have a narrow transient region. Such a source could be produced from uranium and moderators containing light elements such as hydrogen, deuterium and beryllium. The proposed technique should prove useful in a system difficult to extend lengthwise on account of the source intensity or because of the quantity of materials that would be required.

The author is grateful to Prof. T. Shibata for his encouragement. He is also indebted to Mr. M. Utsuro for his valuable advice and discussions.

——REFERENCES——

(1) DUNLOP, J.H., UHRIG, R.E.: *Symp. Neutron Noise, Waves & Pulse Propagation, Florida,* (1966).
(2) SUMITA, K., TAKAHASHI, A.: *Japan-U.S. Seminar Nucl. Reactor Noise Analysis,* Tokyo & Kyoto, (1968).
(3) WADA, M., UTSURO, M.: *Ann. Rep. Res. Reactor Inst., Kyoto Univ.*, **3**, (To be published).
(4) UTSURO, M., INOUE, K., SHIBATA, T.: *J. Nucl. Sci. Technol.*, **5**[6], 298 (1968).

Journal of NUCLEAR SCIENCE and TECHNOLOGY, **7** [9], p. 476~478 (September 1970).

Angular Information in a Gridded Chamber and Its Application

Mitsuru MIZUHO*

Received April 27, 1970

Output pulses from gridded chamber can provide much information on the properties of ionized field, such as particle range, specific ionization, orientation (or location) of the track, drift velocity and mass. There are several papers on the measurement of the angle θ made by particle tracks in reference to the direction of the electric field.

Bochagov, Vorob'ev & Komar[1][2] have used the grid pulse as the measure of angle θ. An energy resolution of 14 keV (FWHM) was achieved by the electronic collimation utilizing a single channel pulse-height analyzer (SCA) for the ^{224}Ra alphas, though at the expense of counter efficiency.

Döke, Ogawa & Tsukuda[3]~[5] have retained high efficiency by making use of a double gridded chamber which has an additional grid for signal extraction.

Facchini, Gatti & Pellegrini have, on the other hand, utilized the difference in the pulse shape of the anode (collector) pulses. The leading edge of the voltage pulse was picked off by means of delay line clipping and this was used as the measure of the angle θ.

In the present method also, the difference in the shape of the anode pulses are utilized. The rise time of the anode pulses, in current or voltage mode, is analyzed by rise time to pulse-height converter (RHC) — JAERI model 154[6], and this is used for obtaining the angle information or else for electronic collimation. The characteristics of the angle information yielded by the present method were investigated using an ^{241}Am source covered with thin (2.0 mg/cm^2) Al-foil. This source arrangement gives different energies for α particles of different angles θ, and simulates the recoil protons from the thin radiator in a fast neutron spectrometer. It is expected that the rise time of the anode pulse is, roughly estimated, proportional to the component $R\cdot\cos\theta$, where R is the range of the particle of angle θ. The relation of energy *vs.* $R\cdot\cos\theta$

* Radioisotope School, Japan Atomic Energy Research Institute, *Hon-Komagome, Bunkyo-ku, Tokyo.*