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Coupling Parameters for Partially Reflected Reactors

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For situations in which the standard point kinetic model does not adequately characterize the kinetic behavior of a reflected system, the Avery-Cohn[1,2] differential equations can be used.[3] However, these equations require that we determine the coupling parameters between the core and the reflector, f_{cr} and f_{rc}. The coupling parameter, f_{cr}, represents the probability that a neutron in the core will leak into the reflector, and the coupling parameter, f_{rc}, represents the probability that a neutron in the reflector will scatter back into the core.

As discussed in Reference 3, these two coupling parameters can be calculated from the multiplication factor of the bare core, k_c, the effective multiplication factor of the integral system, k_{eff}, and the fraction of system neutrons absorbed in the core region, P_{ca}. The methodology presented in Ref. 3 was described for a fully reflected system, but it is also applicable to some types of partially reflected systems. In particular, it is applicable to those systems where neutrons leaving any core surface not contiguous to the reflector have a zero probability of entering the reflector (see examples in Figs. 1a and 1b). In other words, these surfaces have a *view factor* of 0 to all reflector surfaces in the system.

However, if the view factor between an unreflected core surface and a reflector surface is not zero (see Figs. 1c and 1d), then the aforementioned methodology has to be modified. To calculate f_{cr}, we must include an estimate of the single-pass probability that a neutron escapes from the core to infinity, f_{ci}. This is accomplished by including a view factor(s) in the calculations that accounts for the fraction of neutrons that are not traveling on a line intersecting some portion of the reflector.

To illustrate this modification, assume the partially reflected system shown in Fig. 1c. The fraction of neutrons escaping from each core surface, ${}^jP_{ci}$, must be reduced by the appropriate view factor F_{cj-i} to determine the fraction that leak to infinity. Calculation of the single-pass core leakage probability, f_{ci}, depends on the sum of the modified values from each core surface. That is,

$$f_{ci} = (1-f)\,({}^uP_{ci}F_{cu-i} + {}^lP_{ci}F_{cl-i}) \quad , \tag{1}$$

where f = the fraction of neutrons that return to the core after having leaked into the reflector,
${}^uP_{ci}$ = the fraction of neutrons that leak from the upper axial core surface,

$^{l}P_{cl}$ = the fraction of neutrons that leak from the lower axial core surface, and
$F_{cj\text{-}i}$ = the view factor from the j^{th} core leakage surface to infinity.

The fraction of neutrons that leak from the upper and lower surfaces can be estimated in one of two ways. The easiest (but least accurate) way is to use the bare-core solution and simply integrate the neutron currents over these two leakage areas. The second way is to generate an interim solution for a system similar to Fig. 1a and predict f_{ci} using the methodology outlined in Ref. 3. The second method is preferred because it more closely approximates the flux distribution of the system shown in Fig. 1c.

If we assume that the leakage current is uniform and diffuse, then the view factors $F_{cj\text{-}i}$ are readily obtained from any number of standard references dealing with thermal radiation heat transfer. For the configuration shown in Fig. 1c, $F_{cu\text{-}i}$ and $F_{cl\text{-}i}$ are equal and correspond to the view factor for two parallel circular disks separated by a distance h and having equal radii ($\rho_1 = \rho_2$) with centers along the same normal.[4]

$$F_{cj-i} = \frac{1}{2}\left(X - \sqrt{X^2 - 4\left(\frac{R_2}{R_1}\right)^2}\right) \quad , \tag{2}$$

where

$$X = 1 + \frac{1 + R_2^2}{R_1^2} \quad , \tag{3}$$

$$R_1 = \frac{\rho_1}{h} \quad , \tag{4}$$

and

$$R_2 = \frac{\rho_2}{h} \quad . \tag{5}$$

As described in Ref. 3, the single-pass probability, f_{ca}, is given by

$$f_{ca} = (1 - f)\,P_{ca} \quad , \tag{6}$$

where P_{ca} is the fraction of neutrons absorbed in the core region. The coupling parameter, f_{cr}, is then obtained from

$$f_{cr} = 1 - (f_{ca} + f_{ci}) \quad , \tag{7}$$

and the coupling parameter, f_{rc}, is obtained from

$$f_{rc} = \frac{f}{f_{cr}} \quad . \tag{8}$$

As with a fully reflected system, f is determined from the difference in the multiplication factors corresponding to the bare core solution and the integral system solution (i.e., $f = k_{eff} - k_c$).

Although we cannot generalize these equations for all partially reflected systems, we can state that the methodology described in Ref. 3 can be easily modified to a wide variety of systems with partial reflection.

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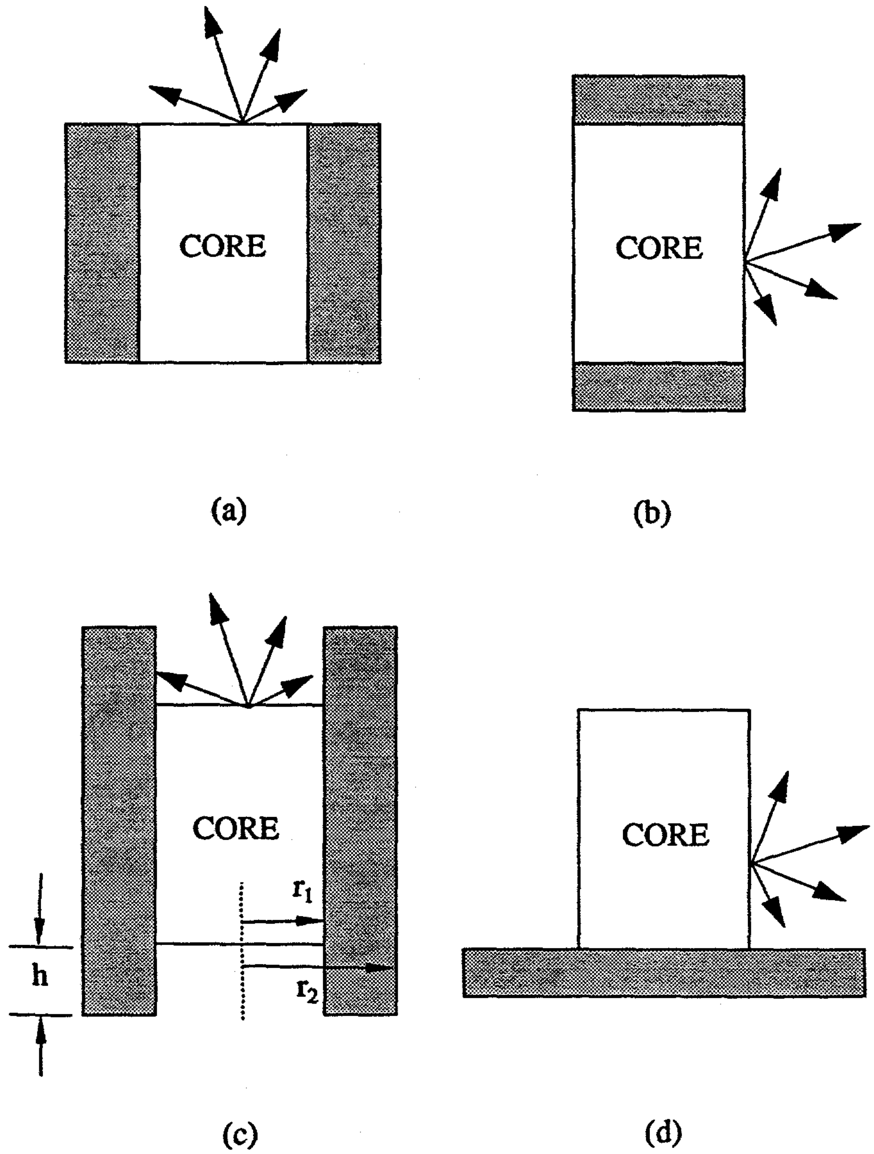

Fig. 1. Four examples of partially reflected reactors.