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NUMERICAL CALCULATION PROCEDURE FOR CRITICALITY PARAMETERS OF THE TWO-ZONE REFLECTED REACTOR WITH FLAT CENTRAL ZONE

by

T.Boševski and P.Strugar

Introduction

In determining the criticality parameters of a two-zone reactor with flat central zone one encounters a numerical problem requiring the solution of a system of two non-linear equations. To solve them the Newton method, which proved convenient, was used in this work.

By comparing our results with those reported in /3/ one obtains about 5% smaller values of both the radius of the flat zone and of the radial buckling of the outer zone. This discrepancy probably results from some approximations used in solving the same system of equations /3/ where the procedure from /2/ was applied, whereas the calculation time is by one order of magnitude smaller.

Numerical procedure

The method of effective boundary conditions for determining the criticality parameters of the reactor with flat central zone leads to the following system of two non-linear equations /1/ and /2/:

$$f_1(\beta_r,R_1)=(\frac{R_1}{R})^2+\frac{R_1}{R}(1+bT_r\beta_r^2\nu^2)\left[J_1(\beta_r R_1)Y_1(\beta_r R)-\right.$$

$$\left.-Y_1(\beta_r R_1)J_1(\beta_r R)\right]-F_r^{-1}=0 \qquad (1)$$

$$f_2(\beta_r,R_1)=J_1(\beta_r R_1)Y_o(\beta_r R)-Y_1(\beta_r R_1)J_o(\beta_r R)+$$

$$+T_r\beta_r\left[Y_1(\beta_r R_1)J_1(\beta_r R)-Y_1(\beta_r R)J_1(\beta_r R_1)\right]=0, \qquad (2)$$

where

- R – reactor core radius
- T_r, b – reflector parameters
- F_r – radial flux form factor
- $\nu = (L^{-2}+\tau^{-1})^{\frac{1}{2}}$
- L – neutron diffusion length in outer zone
- τ – neutron age in outer zone
- R_1 – required radius of flat zone
- β_r – radial buckling of outer zone

The Newtron method was chosen to solve this system because it allows a rough knowledge of the initial values of the independent variables.

Let $\bar{f}=\begin{bmatrix} f_1 \\ f_2 \end{bmatrix}$, $\bar{x}=\begin{bmatrix} \beta_r \\ R_1 \end{bmatrix}$

Now the system of equations (1), (2) may be written

$$\bar{f}(\bar{x}) = 0, \qquad (3)$$

and the approximation of the order (k+1) of varibale $\bar{x}$ is

$$\bar{x}^{(k+1)} = \bar{x}^{(k)} - W^{-1}(\bar{x}^{(k)})\bar{f}(\bar{x}^{(k)}), \qquad (4)$$

where

$$W = \left[\frac{\partial f_i}{\partial x_j}\right], \quad (i,j = 1,2) \qquad (5)$$

With folowing simbols

$$z_1(\beta_r,R_1) = J_1(\beta_r R_1)Y_o(\beta_r R) - J_o(\beta_r R)Y_1(\beta_r R_1), \qquad (6)$$

$$z_2(\beta_r,R_1) = J_1(\beta_r R_1)Y_1(\beta_r R) - J_1(\beta_r R)Y_1(\beta_r R_1), \qquad (7)$$

$$z_3(\beta_r,R_1) = J_o(\beta_r R_1)Y_1(\beta_r R) - J_1(\beta_r R)Y_o(\beta_r R_1), \qquad (8)$$

$$z_4(\beta_r,R_1) = J_o(\beta_r R1)Y_o(\beta_r R) - J_o(\beta_r R)Y_o(\beta_r R_1), \qquad (9)$$

the functions $f_1(\beta_r,R_1)$, $f_2(\beta_r,R_1)$ and their partial derivatives are

$$f_1 = \left(\frac{R_1}{R}\right)^2 + \bar{\mu}\,\frac{R_1}{R}(1+bT_r\beta_r^{2\nu^{-1}})z_2 - F_r^{-1} \qquad (10)$$

$$f_2 = z_1 - \beta_r T_r z_2 \qquad (11)$$

$$f'_{1,R_1} = 2\,\frac{R_1}{R^2} + \bar{\mu}\,\frac{R_1}{R}(1+bT_r\beta_r^{2\nu^{-1}})\,\beta_r\,z_3 \qquad (12)$$

$$f'_{1,\beta_r} = \bar{\mu}\,\frac{R_1^2}{R}(1+bT_r\beta_r^{2\nu^{-1}})z_3 - \bar{\mu}\,R_1\,\frac{2}{R\beta_r}\,z_2 - (1+bT_r\beta_r^{2\nu^{-1}})z_1 \qquad (13)$$

$$f'_{2,R_1} = \beta_r(z_4 - \beta_r T_r z_3) - \frac{f_2}{R_1} \qquad (14)$$

$$f'_{2,\beta_r} = R_1(z_4 - \beta_r T_r z_3) - (R\beta_r T_r + \beta_r^{-1})z_1 - (R-T_r)z_3 \qquad (15)$$

In investigating the function f_1 the following expression for zero approcimation of variable R_1 was obtained

0,45

$$R_1^{(o)} = R \left[1 - \frac{1-F_r^{-2}}{1-F_{ro}^{-2}} \right], \tag{16}$$

where F_{ro} is the flux form factor for a reactor without flat zone, which according to /1/ approximately is

$$F_{ro}^{-1} = 0.433 \left(1 + \frac{2T_r}{R+T_r}\right) \tag{17}$$

For the boundary condition

$$\phi(\beta_r, R_x) = J_o(\beta_r R_x) Y_1(\beta_r R_1) - Y_o(\beta_r R_x) J_1(\beta_r R_1) = 0 \tag{18}$$

in /4/ is given an approximative form

$$\beta_r = \frac{2.37 - 1.55\alpha + 0.77\alpha^2}{R_x(1-\alpha)}, \tag{19}$$

where R_x is the extrapolated radius and $\alpha = R_1/R_x$.

The zero approximation $\beta_r^{(o)}$ is obtained from the eq. (19) taking

$$R_x^{(o)} = R + T_r \quad \text{and} \quad \alpha^{(o)} = R_1^{(o)}/(R+T_r)$$

With these zero approximations, convergence is very fast. Only with two iterations β_r and R_1 are determined with a relative error below 0.01%.

Results

Input data

1. Reactor core radius $R = 250$ cm
2. Radial reflector thickness $T = 37$ cm
3. Axial geometrical buckling $B_z^2 = 0.4111\ m^{-2}$
4. Neutron age in outer zone $\tau = 183.9\ cm^2$
5. Neutron diffusion area in outer zone $L^2 = 214.2\ cm^2$

Table 1

F_r	R_1 (cm)		B_r^2 (m^{-2})	
	"BUKT" /3/	"REDIR"(*)	"BUKT" /3/	"REDIR"(*)
1.160	163	156.8	2.490	2.229
1.180	157	150.4	2.307	2.085
1.220	145	139.0	2.033	1.865
1.2710	130	124.4	1.793	1.665
1.3083	121	114.8	1.666	1.559
1.3457	112	105.6	1.569	1.473
1.3831	103	96.8	1.484	1.404
1.4205	94.4	88.4	1.418	1.347

(*) For "REDIR" $b = 0.2589$

$T_{ekv} = 41.50$ cm

The same results are graphically shown in Figs. 1 and 2.

As can be seen from the comparison with the results from /3/, the values for R_1 and β_r^2 are by about 5% smaller for the same input data. So large a discrepancy probably results from the approximation of eq. (2) introduced in /2/.

The calculation time in this procedure, as compared with the corresponding time of the BUKT programme /3/, solving the approximative quation (2) given in /2/, is by one order of magnitude smaller.

References

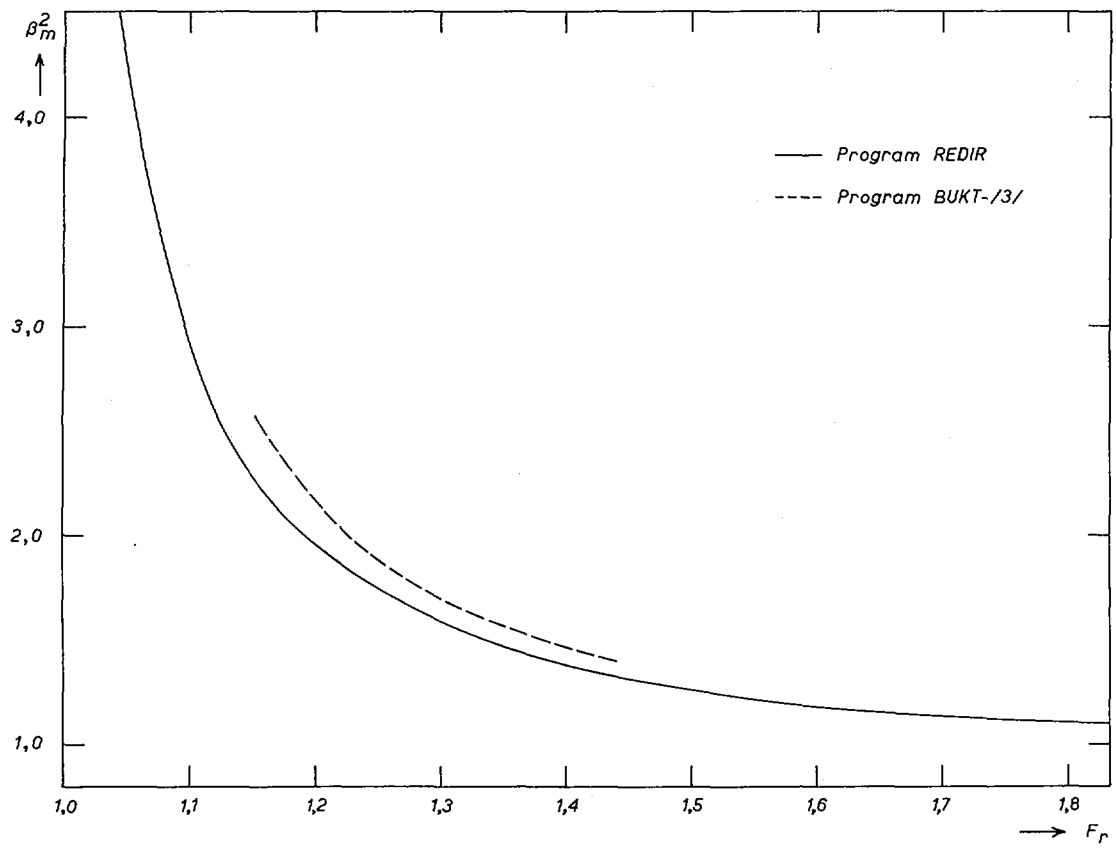
1. A.D.Galanin, Thermal Reactor Theory. Moscou, 1959 (in russian).

2. B.Fredin, A two-group corrected calculation of the flux used in BCP-5. AE-RFR-494 (in swedish).

3. T.Boševski, Determination of initial core configuration for BHWR-200 MWe. AE-RFR-551.

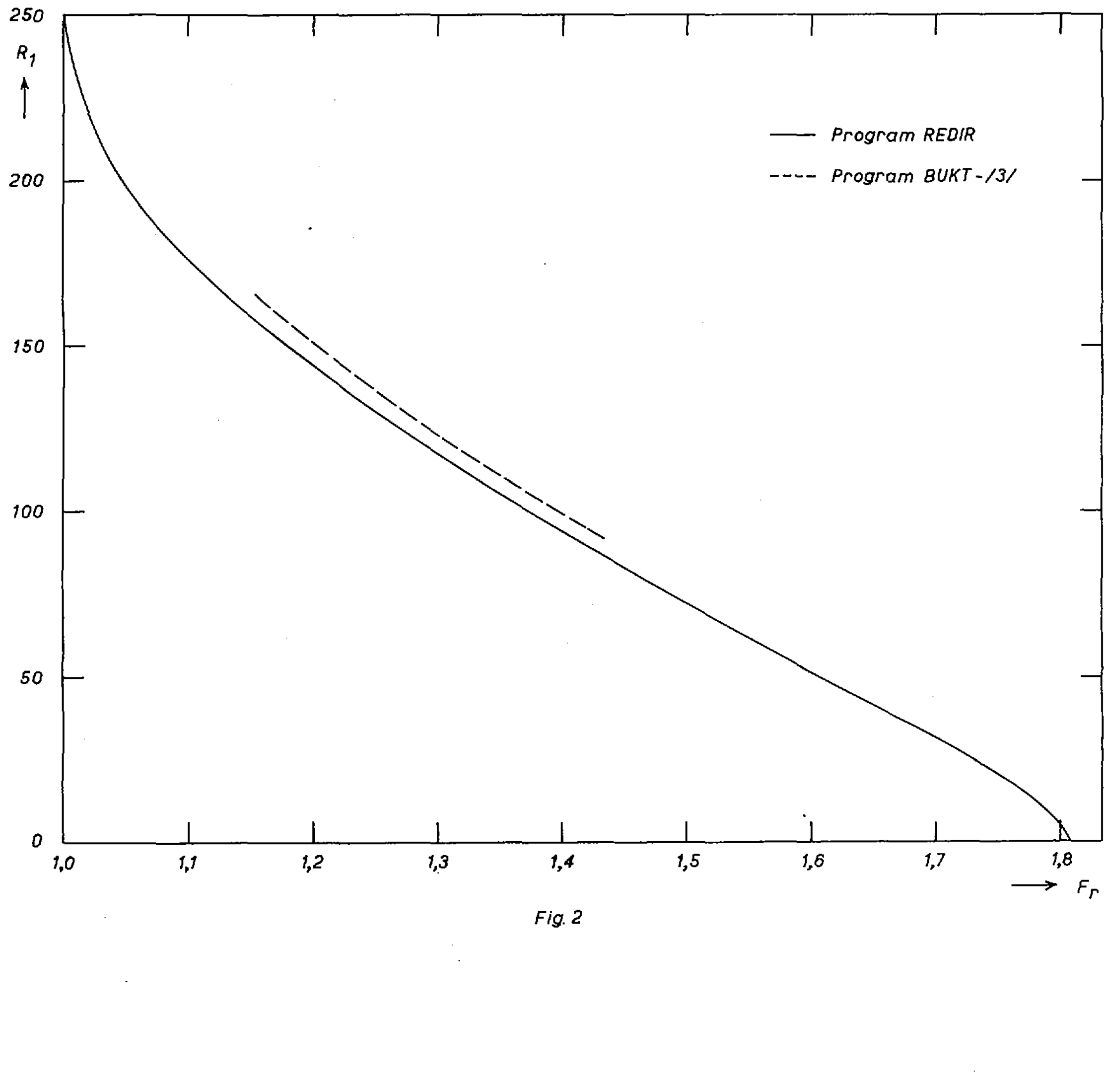
4. S.Linde, Approximation of "Buckling for two zons reactor.TPM-RFN-34 (in swedsh).

5. B.P.Demidovič, I.A.Maron, Numerical mathematics. Moscou, 1960 (in russan).



β_m^2
4,0
3,0
2,0
1,0
1,0
1,1
1,2
1,3
1,4
1,5
1,6
1,7
1,8
F_r
Program REDIR
Program BUKT-/3/

Fig. 1



250
R_1
200
150
100
50
0
1,0
1,1
1,2
1,3
1,4
1,5
1,6
1,7
1,8
F_r
Program REDIR
Program BUKT-/3/

Fig. 2

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