SHORT NOTE

On-Line Calculational Method for Evaluating the Power Distribution in a Nuclear Reactor Core

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A new method for evaluating three-dimensional power distribution in a nuclear reactor core is developed, which is suitable for on-line core performance calculation and useful for economical, safe operation of a nuclear power station. This method is based upon the numerical calculation of power distribution by a coupled nuclear-thermal-hydraulic code equivalent to "FLARE"[(1)], the well established three-dimensional boiling water reactor simulator. The calculated power distribution is then corrected to make it consistent with the neutron flux distribution measured by ion chambers (LPRM) placed in various parts of the core region.

1. Estimation Procedure

The whole estimation procedure, illustrated in **Fig. 1**, consists of the following six steps:

(1) Power, void and channel flow distributions are calculated by the FLARE equivalent code.

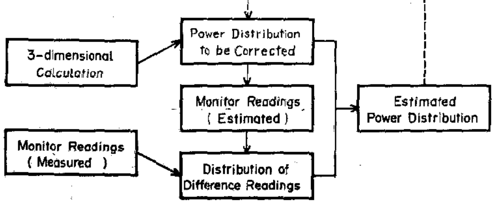

Fig. 1 Process of estimating power distribution

(2) LPRM readings are estimated from the results of step (1), assuming that neutron flux at the ion chamber position is proportional to the average power density of the surrounding eight fuel segments.

(3) Estimated LPRM readings are compared with the measured readings, and the difference between the two is calculated after appropriate normalization.

(4) The differences in readings on the pseudo-monitored strings, where there are no actual monitors, are estimated by radial and axial interpolations.

(5) The differences are redistributed to the power density of each fuel segment as the estimated error of the power density.

(6) The above corrected power distribution thus obtained is substituted for the power distribution of step (1) and steps (2)~(6) are repeated several times if necessary.

In step (4), the differences in readings are axially interpolated at the monitored strings by the polynomial approximation, and then radially interpolated. The method of radial interpolation and redistribution of the differences in readings used in steps (4) and (5) are illustrated in **Fig. 2**. The difference at a pseudo-monitored position is assumed to be the average of four differences at the surrounding monitored or pseudo-monitored positions located at equal distances from the position to be interpolated.

Redistribution of the difference of readings is performed under the geometrical condition shown in Fig. 2 by using the equation.

$$\left.\begin{aligned} &\delta P_j=\sum_{i=1}^{4} w_{ij}\,\delta R_i \\ &\sum_{i=1}^{4} w_{ij}=1,\quad w_{ij}\propto\frac{1}{r_{ij}} \end{aligned}\right\}, \tag{1}$$

where

δP_j: Difference of power density of segment j

δR_i: Difference between measured and estimated LPRM readings at location i

w_{ij}: Weighting function

r_{ij}: Distance between center of fuel segment j and location i.

The core average power density is normalized to unity before and after correction. Measured and estimated LPRM readings are also normalized

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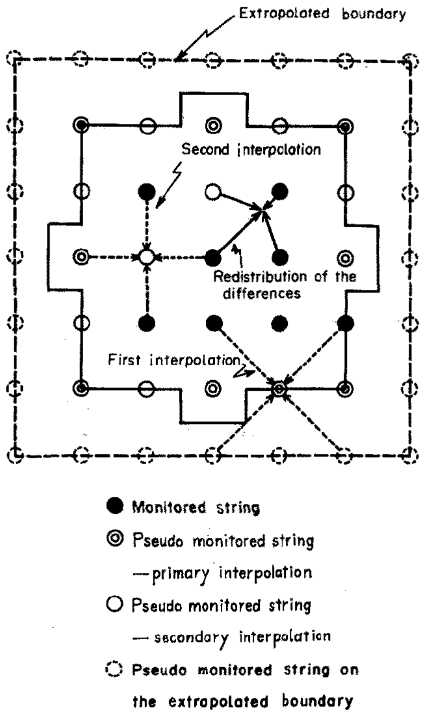

Fig. 2 Interpolation and redistribution of difference between the two kinds of readings

so as to let the average value be the same as at the actual LPRM location.

2. Results and Discussion

The following three substitutions are adopted for a numerical experiment aimed at evaluating the validity of this method:

(1) The power distribution from the FLARE calculation is substituted for the accurate power distribution.

(2) A rough estimation of power distribution obtained by the unconverged FLARE calculation with about 10% error is substituted for the power distribution to be obtained by the three-dimensional calculation in Fig. 1 and which will be corrected by using the measured neutron flux distribution.

(3) Estimated LPRM readings from the result of the exact FLARE calculation is substituted for the actual LPRM readings.

If the actual LPRM readings are exactly proportional to the average power density of the surrounding eight fuel segments, the results of the numerical experiments employing the above three substitutions should prove the validity of this method when applied to actual reactor cores.

The results so far obtained are very satisfactory. An example of the axial power distribution in JPDR estimated by the numerical experiment described above is given in **Fig. 3**. **Figure 4** shows the radial power distribution in the same case. The power distribution can be estimated with a maximum error of 5%, and is usually within 3%. The computer running time with the HITAC 5020 F is about 20 sec, and about the same time is estimated to be sufficient for the on-line process computer HIDIC-500, when the initially assumed power distribution is such as given by the periodic core performance cal-

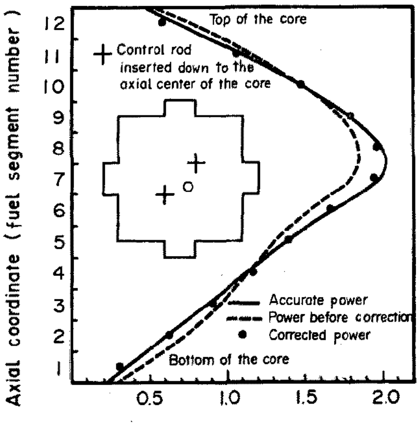

Fig. 3 Axial power distribution estimated by numerical experiment

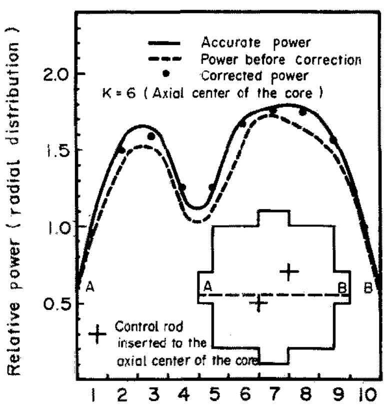

Fig. 4 Radial power distribution estimated by numerical experiment

culation previously obtained.

The main causes of errors introduced by this method lie in the following three procedures:

(1) Estimation of the LPRM readings
(2) Interpolation of the difference of readings
(3) Redistribution of the difference to segment power density

It should be noted here that even if the accuracy of the calculated power distribution is about 80%, the errors introduced by this method only affect the remaining 20%. Thus, if the error introduced in the above procedure is about 20%, the total error would still amount to only 4%. This is the main advantage of this method.

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SHORT NOTE

Effect of Flow on Pressure Wave Propagation in Two-Component Two-Phase System

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1. Introduction

The observed velocities of pressure disturbances in flowing media should correspond to the combined result of the propagation velocity of the disturbance through the medium and the velocity of the medium itself, the two superposed linearly, as in the case of sound waves in the presence of wind, since pressure waves are londitudinal vibrations of the medium. However, in the case of flowing two-phase media, complications arise due to the existence of slip, which imparts a dynamic, *i.e.*, transient, as well as a stationary effect on the pressure wave propagation. Data now available is limited in number, and cover only the lower ranges of flow velocity. An experiment has been performed to examine the effect of flow on pressure wave propagation in air-water medium.

2. Experimental Device and Procedure

The test section is constituted of a straight channel 1.3 m long, with a rectangular cross section 20×25 mm, made of acrylite, joined to converging entrance and diverging exit channels which convert the flow smoothly from circular to rectangular section and vice versa (see **Fig. 1**). The circular part is 50 mm I.D. Diaphragm rupturing devices were installed slightly obliquely to the entrance and exit zones in order to apply step-up or -down pressure disturbances to the flowing air-water medium in the directions common or opposite to the flow, respectively.

The transient pressures and void fractions were measured at two points along the straight section separated by a distance of 1 m, with use made of semiconductor piezo resistance type pressure detectors and dynamic void meters of electric resistance type. The stationary pressure and void fraction were measured by a Bourdon tube gage and a RC-filtered void signal, respectively, at mid-point along the straight section. The average velocities of the gas and liquid were evaluated from the flow rates of the respective phases, and void fraction measured, based on the continuity

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