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Development Status of THALES Code

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1. Introduction

KNF has been developing the reactor core design codes for the nuclear power plants to establish the KNF design code system. The core thermal hydraulic design code, THALES (Thermal Hydraulic AnaLyzer for Enhanced Simulation of core) has been developed to be β version. This paper presents the descriptions and characteristics of THALES-β and shows the sample test results.

2. Code Descriptions and Characteristics

2.1 Code Requirements

THALES code [1] has been developed for the core thermal hydraulic design of OPR1000, APR1400, and Westinghouse type nuclear power plants in Korea, based on the following two requirements [2].

1) The functions required to current core thermal hydraulic design activities. The functions are the analysis of core flow field and heat transfer, the calculation of thermal hydraulic parameters, and the prediction of critical heat flux, etc.
2) The performance comparable to the subchannel analysis codes such as COBRA family codes.

2.2 Governing Equations

The control volumes (CV) to reduce the governing equations are based on the subchannel geometry of the fuel assemblies as shown in the Fig. 1. The governing equations of mass, axial momentum, lateral momentum, and energy are respectively as follows:

$$A\frac{\partial \rho}{\partial t}+\frac{\partial m}{\partial z}+\sum e_{ij}w=0 \qquad (1)$$

$$\frac{\partial m}{\partial t}+\frac{\partial}{\partial z}\left(\frac{v'}{A}m^2\right)+\sum e_{ij}wu^*=-A\frac{\partial p}{\partial z} -\frac{1}{2}\left(\frac{f\phi^2 v_f}{D_h}+\frac{K_{SG}}{\Delta z}v'\right)\frac{m^2}{A}-Ag\rho-c_T\sum w'\Delta U \qquad (2)$$

$$\frac{\partial w}{\partial t}+\frac{\partial w\bar{u}}{\partial z}=\frac{s}{l}\left(p_i-p_j\right)-\frac{1}{2l}K_G v'^*|w|\frac{w}{s} \qquad (3)$$

$$A\left(\rho\frac{\partial h}{\partial t}-h_{fg}\frac{\partial \psi}{\partial t}\right)+m\frac{\partial h}{\partial z}+\sum e_{ij}w\left(h^*-h\right) +\frac{1}{\mathrm{Pr}_t}\sum e_{ij}w'\Delta h=q' \qquad (4)$$

where, e_{ij} : 1 for $i<j$, -1 for $i>j$

$v'=\frac{\chi^2}{\alpha\rho_g}+\frac{(1-\chi)^2}{(1-\alpha)\rho_f}$ specific volume for momentum

c_T = turbulent momentum factor

$\psi=(1-\alpha)\rho_f\chi-\alpha\rho_g(1-\chi)$ Tong's special function

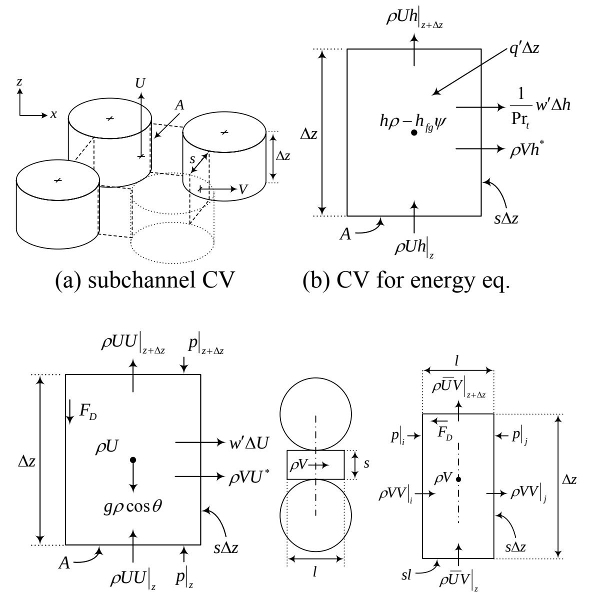
h^* = enthalpy of donor subchannel

$\mathrm{Pr}_t=\varepsilon_t/\alpha_t$ turbulent Prandtl number

$w'=\varepsilon_t\rho\left(\frac{S}{\ell}\right)$ turbulent lateral flow

2.3 Numerical Scheme

The governing equations are discretized to the finite difference forms. To make matrix to solve the governing equations, the staggered mesh [Fig. 2] is used to remove the pressure discrepancy of the existing COBRA family codes.



(a) subchannel CV (b) CV for energy eq.

(c) CV for axial mom. eq. (d) CV for lateral mom. Eq.

Fig. 1. Control volumes for the governing equations

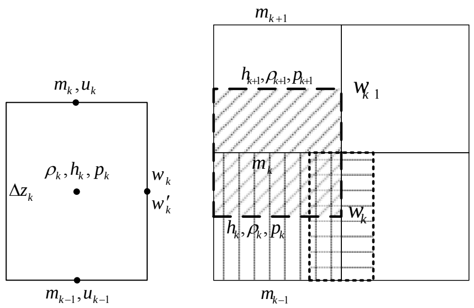


Fig.2. Control volumes for 1/2 staggered mesh

Finally we solve the following NxN linear matrixes. N is the number of subchannels.

$$[A]\{dp/dz\}_k = \{B\} \text{ for the momentum eq.}$$
$$[A]\{h\}_k = \{B\} \text{ for the energy eq.}$$

The numerical technique to solve two matrixes is the preconditioned by-conjugate gradient method (PBCGM). The main differences between THALES-β and other thermal hydraulic codes are summarized in Table I.

Table I: Differences between THALES-β and other codes

	THALES-β	TORC [3]	COBRA-EN[4]
Flow solution	*dp/dx*	*w*	*dp/dx*
Mesh (Axial node)	Staggered	Non-staggered	Non-staggered
Energy eq. matrix	Used	Not-used	Used
Matrix solver	PBCGM	PBCGM	Gauss-Seidel
Steam table	ASME	ASME	EPRI
Precision	double	double	single

2.4 Thermal Hydraulic Models

The thermal hydraulic models implemented in THALES-β are summarized in Table II. THALES-β has the functions and thermal hydraulic models needed to core thermal hydraulic design.

Table II: Thermal hydraulic models of THALES-β version

TH Parameters	Correlation/Model
Turbulent mixing	No turbulent mixing $w' = a\,\mathrm{Re}^b\,\bar{G}s$ $w' = a\,\mathrm{Re}^b\,\bar{G}D_h(s/l)$, etc.
Friction	Darcy(Moody)
Two-phase friction multiplier	Homogeneous Sher-Green and Martinelli-Nelson Armand, EPRI
Void	Homogeneous Modified Martinelli-Nelson Armand, Constant slip ratio
Heat transfer coefficient	Dittus-Boelter Jens-Lottes, Thom, Chen
CHF	KCE-1, CE-1, WRB-2

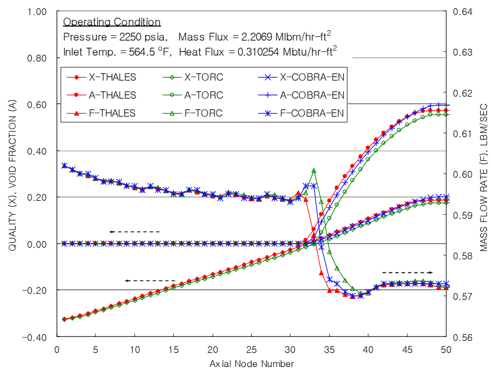


Fig.3. Comparison of the results from THALES-β and others

2.5 Performance

THALES-β shows the good results from the sample code runs modeling a 1/4 fuel assembly compared to other codes as shown in Fig. 3.

3. Conclusions

KNF has been developed THALES-β version for the application to the core thermal hydraulic design. The code has the functions and performance required for the purpose. The test results show that the THALES-β has reasonable accuracy and is comparable to the codes being used to the core thermal hydraulic design. The numerical scheme with the matrix solver and the thermal hydraulic models of the code will be improved continuously and verified to get the license from the government authorities.

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