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Comparative Analysis of FAST-2 and MATRA-S Code Using Validation Problem

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1. Introduction

Online core monitoring and protection system in SMART core estimates the core status based on a real time calculation of operating margin. The operating margin is to need the quick DNBR calculation for limiting channel that is a hypothetical channel resulted from conservative conditions combined. FAST code[1] is developed to calculate quickly the MDNBR calculation for this purpose.

Recently, the FAST code, named as FAST-2, is entirely improved as adopting an expanded multichannel ability, iterative linear solver to improve the calculation speed and robustness of linear system of equations, and transient term considering unsteady condition.

In this study, validation of FAST-2 is performed with comparing the experiment results which are used to validate MATRA-S code[2]. These validation problem set are basically consisted of the single phase and two phase condition where test geometry is constricted as a bundle geometry.

2. Methods and Results

2.1 FAST-2 Code Description

Generally, FAST-2 code is used as a reference code with the fast running DNBR calculation module embedded in core monitoring and protection system. The fast calculation speed, least size of memory and robustness on limiting condition should be required in this system. The FAST-2 code is developed to satisfy these requirements with enhancements as shown in Table 1. Table 1 shows improved code accuracy and code functionality compared with original FAST code

In an embedded version of FAST-2, it is slightly modified and simplified to satisfy the requirements of the size of memory which is restricted in the core monitoring and protection system in SMART core. It is known that the preprocessor part of code, generation of geometry and matrix of linear system of equations, has a dominant part of memory size The prescribed geometry and matrix file is used to remove the subroutine. It allows to save total CPU time of 10 ~ 15 % compared with the FAST-2 code. Additionally, core model of FAST-2 code is developed with least number of subchannels which can simulate multichannel effect ,adequately.

Table 1. Approximate solution factors of root finding method

Code	FAST-1	FAST-2
Governing Equation	Steady HEM	Transient HEM
Memory Management	Fixed Memory	Dynamic Memory
Geometry	4 Channel Only	Multichannel
Linear Solver	Cramer's rule	Direct Solver
Flow Solver	Non-iterative marching scheme	Non-iterative mutli-channel marching scheme

2.2 MATRA-S Validation Problems

MATRA-S validation problems are well designed to access the code accuracy based on validation matrix of other subchannel codes such as Vipre-01, TORC, COBRA family. The validation matrix used in this study is described in Table 2[2]. All of experiments were compared with the MATRA-S calculation on the P/M (prediction to Measured) value.

FAST-2 code will be estimated with comparisons of experimental data and code-to-code where MATRA-S code is used as a reference code.

Table 2. Approximate solution factors of root finding method

Test type		Test data used in code validation			
		TORC	THINC-4	VIPRE-01	MATRA-S
Single-phase flow	CNEN 4x4 mixing		●		●
	WH 14x14 blockage	●	●	●	●
Two-phase flow	GE 3x3 mixing		●	●	●
	ISPRA 4x4 mixing				●

2.3 Validation Results-single phase flow

Firstly, single phase flow tests as shown in Table. 2 are used to estimate the prediction accuracy of flow field. Selected experiments shows flow mixing effect by channel geometry, inlet flow distribution, and grid spacer effect. In reference result of MATRA-S code, MATRA-S shows a good agreement with these experimental results within ± 3 %.

CNEN 4x4 test was conducted to investigate the turbulent momentum transfer due to the channel geometry. Flow distribution at exit plane has a mechanical equilibrium following axial direction. The prediction of MATRA-S and FAST-2 code compared the measured mass flux of each channel at exit plane. The ratio of prediction to measurement (P/M) of MATRA-S and FAST-2 shows the 0.972 to 1.026 and 0.98 to 1.26, respectively. Standard deviation of MATRA-S with 1.3% is much better than FAST-2 with 5.6%.

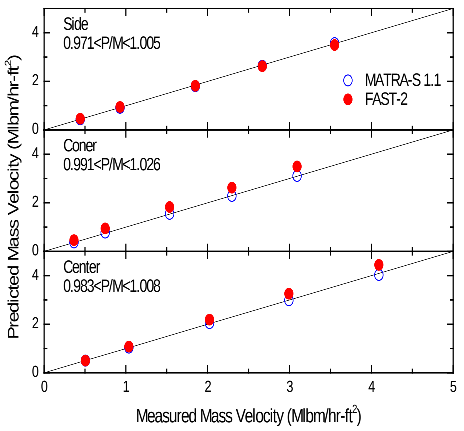

Fig.1. CNEN 4x4 single phase momentum mixing test

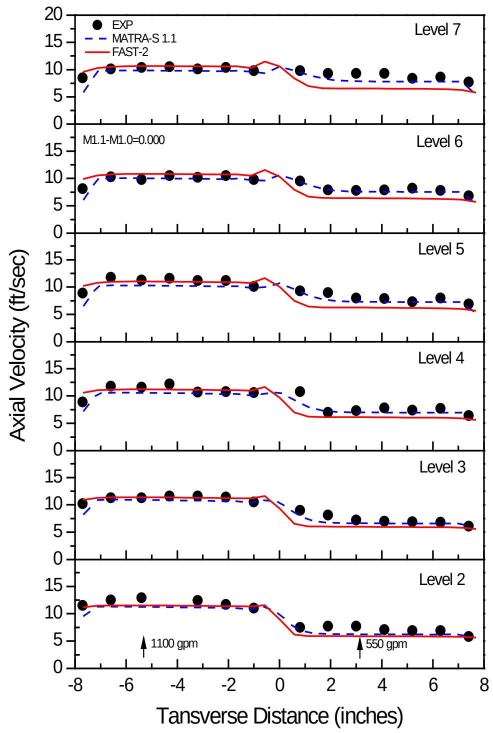

Fig.2. WH 14x14 two assembly inlet flow effect test

Inter-assembly flow mixing test to investigate the effect of the inlet flow blockage was conducted on WH 14x14 two assembly test. Inlet flow of each assembly is controlled with 1100 gpm and 550 gpm which is to simulate flow reduction due to inlet flow blockage. The flow rate of fuel assembly with inlet flow blockage is recovered following axial direction as shown in Fig. 2. The flow recovery of FAST-2 code is less about 10 % than that of MATRA-S code at axial level 7 which is at near exit plane.

FAST-2 code is not sensitive to these mixing effects compared with the MATRA-S code. The main reason of the discrepancy causes to the non-iterative flow solution algorithm of FAST-2 code.

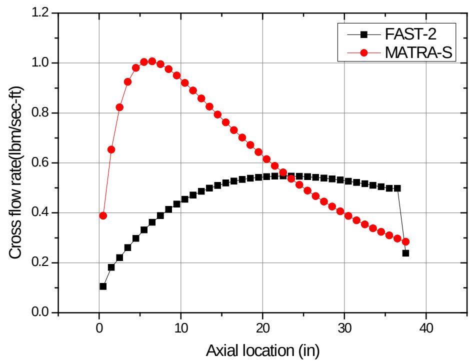

Fig.3. Comparison of cross flow between FAST-2 and MATRA-S

The algorithm can obtain the non-iterative flow field solution based on the assumption of equilibrium of lateral pressure distribution at next axial node. Driving force of cross flow is a lateral pressure difference. In the non-iterative algorithm, the cross flow at next axial node should be known by evaluating the lateral momentum equation in which cross flow is balanced on the lateral pressure difference at downstream grid location. The cross flow can be predicted based on assumption of zero cross flow at the next two node advanced in downstream. The assumption, however, results in generating the cross flow underestimated in Fig. 3. In this Fig. 1 ~ 2, all of results of FAST-2 code shows the tendency of retardation of flow equilibrium due to the underestimated cross flow.

2.4 Validation Results-two phase flow

The equilibrium quality as shown in Fig. 4 ~ 5 are estimated with the two-phase tests on both MATRA-S and FAST-2 code.

GE 3x3 test was plan to validate two phase flow fields of the BWR bundle such as mass flux, enthalpy, and quality. In similar with GE 3x3, ISPRA 4x4 test was also conducted to investigate the quality distribution due to the two-phase mixing. Figure 4 and 5 show the prediction accuracy of quality at each channel types of MATRA-S and FAST-2 code. In the average P/M value, prediction accuracy of MATRA-S code except for corner case is 1.002 for GE 3x3 and 1.041 for ISPRA 4x4. In case of FAST-2, average P/M value is estimated with 1.046 for GE 3x3 and 1.052 for ISPRA 4x4. In the corner channel, quality prediction of MATRA-S and FAST-2 code is overestimated with the experimental data since the mass flow rate in corner is greatly underestimated. MATRA-S code, however, can cure the discrepancy as to change the mixing model to the EVVD (Equal Volume Void Drift) model.

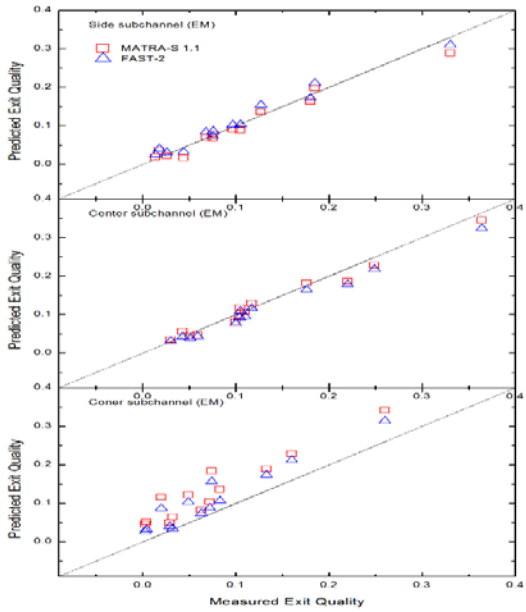

Fig.4. GE 3x3 Exit quality comparison

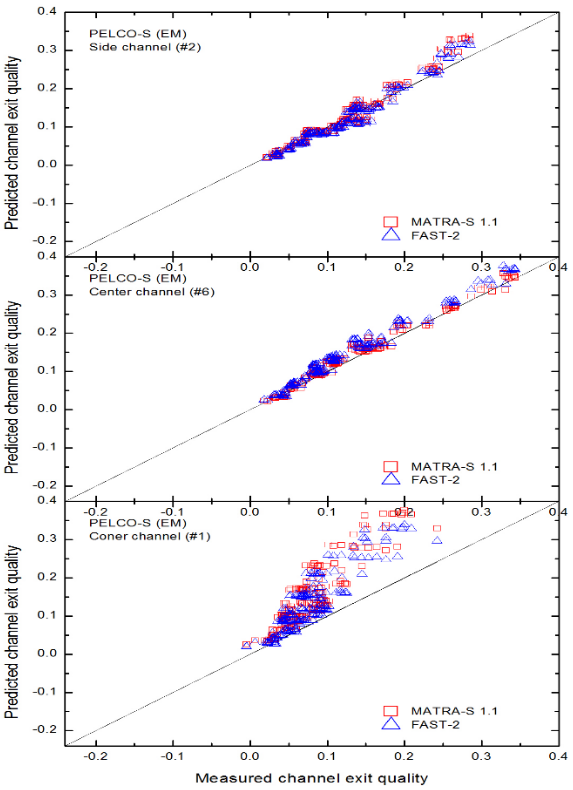

Fig.5. ISPRA 4x4 Exit quality comparison

3. Conclusions

Fast running DNBR calculation code to implement core monitoring and protection system, FAST-2 code, is developed with enhancing the functionality and accuracy compared with original FAST code.

Various validation problems on single and two-phase flow were estimated in comparison with MATRA-S code and experiment results.

In single phase problem, FAST-2 code showed a comparable accuracy compared with MATRA-S code but showed underestimated cross flow that come from non-iterative algorithm. It is a result of pay-off for improving robustness caused by removing the iteration and 2 or 3 times of calculation speed. Acutally, the calculation time of FAST-2 is consumed with 1/5 and 1/10 of MATRA-S calculation time on CNEN 4x4 and WH 14x14 problem and 1/2 or 1/5 in two-phase flow condition.

REFERENCES

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[2] H. Kwon, J.P. Park, K.W. Seo, S.J. Kim, and D. H. Hwang, Validation of a Subchannel Analysis Code MATRA version 1.1, TR-5581, KAERI, 2015.