Study on the Feasibility of CHF Data Integration

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1. Introduction

CHF (Critical Heat Flux) is one of the limiting phenomena which restrict the thermal power of the reactor core. But the mechanism of the CHF occurrence was not found out clearly and even more complicated in reactor core due to the its complex geometry.

Owing to the easy applicability and ability of calculating the local CHF value along the axial direction, most of commercial plants currently use the empirical CHF correlations derived from CHF test data. In order to reflect various geometric characteristics of fuels and wide range of fluid conditions, many different kinds of CHF test are necessary. But the high cost and time burden of the CHF test limit the test range of flow parameter and geometry. And this makes the limitation of applicable range of CHF correlation. As an alternative way of securing the sufficient CHF data, the integration of the test data from the several test sections (TS) can be considered. Until now the split vane shape has been optimized at the geometrical structure of relevant fuel so as to have a best performance. So if TS are equipped the same type of mixing vanes, it might be possible to merge the CHF data using the correction factors which compensate the differences of other geometrical parameters (grid spacing, rod size, heated length, etc.).

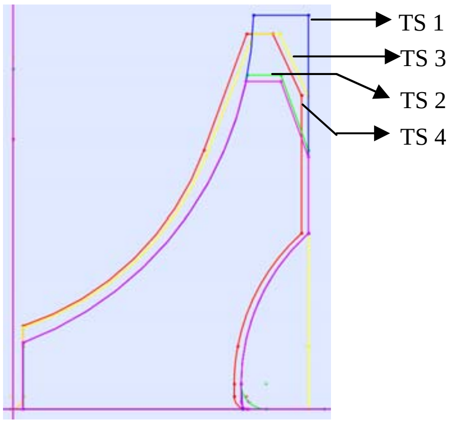

Fig. 1. Mixing Vane Shapes

In this study, the feasibility of CHF test data integration is examined with 4 TS which are equipped with the same type of vanes (split vane) but their shape are different as shown in Fig. 1. Other geometrical characteristics such as heated length, rod size, grid spacing is described in Table 1.

2. CHF Test Data Analysis

In this section, data from four TS are analyzed to verify the performances of the mixing vanes. The direct comparison of the test data is easy to carry out if and only if the geometric characteristics of the test bundle are identical. But this situation is not easy to obtain due to the difference of the as-fabricated heater rod, even with same design. Moreover it is very hard to match the loop operational parameters such as pressure, inlet mass velocity and inlet temperature. The comparison with M/Ps per applicable CHF correlation is widely accepted as an alternative way to identify the performance of CHF test data. WRB-2/TORCK thermal analysis scheme, verified in reference 1, was used for analysis. Because WRB-2 CHF correlation database is independent with above 4 TS data even more WRB-2 CHF correlation is composed of not only geometrical parameters but also local fluid conditions, it is expected to predict the CHF properly along a change of geometric parameter.

3. Integration Feasibility Assessment

3.1 Statistical test for Assessment

As shown in Table 1, the M/P standard deviation of each TS is less than 10% of its mean. So the analysis result is reasonable. But the M/P means of TS 2 and TS 4 are greater than those of TS 1 and 3. It means that mixing vane performance in accordance with vane shape is different or WRB-2 correlation may not be able to predict the CHF properly according to the geometric parameter change. In order to disclose whether or not there is a difference by performance of mixing vane due to its shape, we investigated the geometric parameters differences between TS and looked into the variables of WRB-2 CHF correlation.

The M/P value differences are supposed to come from the fact that WRB-2 CHF correlation doesn't have the rod outer diameter(OD) and pitch as its variable. So we classified TS according to rod OD and pitch to perform statistical analyses. First case was compared to see the effect of differences of geometrical parameters except rod OD and pitch. Second case was compared to see the rod pitch effect on CHF when rod OD is same. Finally case 3 is compared to see the combination effect of differences of rod OD and pitch. The statistical test results are summarized in Table 2.

3.2 Assessment Result Analysis

From the first case result, it was showed that WRB-2 CHF correlation properly describes the heated length and grid spacing effect on CHF. And second case shows that even though they have same rod OD, there still exists the CHF difference due to the rod pitch. Third case shows the need of adjusting rod OD in addition to rod pitch.

To correct the rod OD and pitch effect on CHF, Correction factor, which is defined as a function of rod OD and pitch, was suggested. And the CHF predicted by WRB-2 CHF correlation was modified using this correction factor. In this correction factor development, the pitch to rod OD ratio of TS1 and TS3 was used as a reference value. The M/P statistical value applying this correction factor is shown in Table 1. The final evaluation of CHF test data integration was executed by means of testing the equality of the means. The final results are shown in table. 3.

4. Conclusion

In this study, the thermal performances of various shapes of split mixing vanes were evaluated. It is concluded that CHF performance of various split vanes is comparable to each other regardless of their detail shape. So CHF data deserve to integrate while the data are obtained from TS which are equipped with the same type of mixing vanes regardless of their shape and the other geometrical effects on CHF are properly corrected.

REFERENCES

[1] KangHoon Kim, Study on the Applicability of WRB-2/TORCK to Core Thermal Analysis, KNF-TR-SGH-04005 REV.0, 2004.

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Table 1. CHF Test Data Geometry and Analysis Results

TS	N	Rod Diameter	Rod Pitch	Heated Length	Grid Spacing	WRB-2 M/P(WRB-2 Corrected M/P)	
						Mean	Standard Deviation
1	70	0.374	0.496	168	20/10	1.0711(1.0711)	0.0924(0.0924)
2	107	0.374	0.506	150	15.7	1.1271(1.0830)	0.0896(0.0861)
3	67	0.374	0.496	144	20/10/7	1.0794(1.0794)	0.0960(0.0960)
4	69	0.360	0.485	144	20/10	1.0954(1.0616)	0.0629(0.0609)

* all dimension is inch.

Table 2. Statistical Test for Verification

Case	TS	Homogeneity of Variance			Equality of Mean			Remark
		F	p-value	Result	T	p-value	Result	
1	1 & 3	0.108	0.743	pass	-0.518	0.606	pass	same rod OD & pitch
2	1 & 2	0.651	0.421	pass	-4.015	0.880e-5	fail	same rod OD
3	2 & 4	7.942	0.005	fail	2.553	0.012	fail	different rod OD & pitch

Table 3. Evaluation of CHF test data integration

CASE	Source	Sum of Square	Degree of Freedom	Mean Square	F	P-value	Equality of Mean
WRB-2	Between	0.165	3	0.055	-	-	-
	Within	2.317	309	0.007			
	Sum	2.482	312	-	7.321	0.933e-4	fail
WRB-2 Corrected	Between	0.022	3	0.007	-	-	-
	Within	2.235	309	0.007			
	Sum	2.257	312	-	0.996	0.395	pass