The Analysis for the Effect of Mixing Vane Shape on TDC

Kang Hoon Moon*, Ho Young Park, Kang Hoon Kim, Eung Jun Park, Jung Min Suh
KEPCO Nuclear Fuel Co., 242(Deokjin-dong), 989beon-gil Daedeok-daero, Yuseong-gu, Daejeon, 305-353, Korea
**Corresponding author: khmoon@knfc.co.kr*

1. Introduction

The Thermal Diffusion Coefficient (TDC) is an input parameter to subchannel code, and it is required to predict local flow conditions in a PWR fuel bundle. TDC influences on the prediction of thermal interchange or mixing of thermal energy between the hot subchannel and interconnected adjacent subchannels. The thermal mixing term in the energy equation is generally represented in terms of a non-dimensional inverse Peclet number or TDC [1,2,3]. The parameters associated with thermal mixing can be defined as Eq.(1):

$$\text{TDC} = \overline{Pe} \times \frac{De}{a} \qquad (1)$$

where:

$\overline{Pe}$: Inverse Peclet Number (dimensionless) $= \varepsilon / Va$
De : Equivalent hydraulic diameter, in.
a : Lateral flow area between channels per unit length, in^2/in
ε : Mixing coefficient, in^2/sec
V : Velocity, in/sec

TDC is an important factor to evaluate thermal performance. So, flow temperature maps were obtained from the 5x5 rod bundle test section to assess the thermal performance of corresponding fuels. The flow temperatures were measured by thermocouple at the end of heated length and the centroid of subchannel. There are two typical methods to arrange the hot and cold fuel rods as shown in Fig. 1. Configuration Fig. 1(b) is adopted in this work. This paper presents how to determine the TDC and verifies whether all TDC with the effect of mixing vane shape is valid with respect to current design value.

2. Methods and Results

The methods of enthalpy calibration corrections and TDC determination are described in this section. The test flow conditions and the results of TDC determination include comparing characteristics of test sections which are different slightly from mixing vane shape.

2.1 The method of enthalpy calibration corrections

First, the measured exit temperatures are converted to enthalpies using ASME steam tables [4]. The total enthalpy rise predicted by the subchannel code, TORC [5] is different from that of measured value due to the influence of mixing vane. The main objective of adopting the TDC is not matching the exact enthalpy value but matching the enthalpy distribution of subchannels between measurement and prediction. Therefore secondly, the measured enthalpies are corrected to match the total enthalpy rise using the following Eq.(2):

$$H_c = H_m \times \frac{\sum(W_p \times H_p)}{\sum(W_p \times H_m)} \qquad (2)$$

where:

H_c : Corrected enthalpy in subchannel
H_m : Measured enthalpy in subchannel
W_p : TORC predicted flow in subchannel
H_p : TORC predicted enthalpy in subchannel

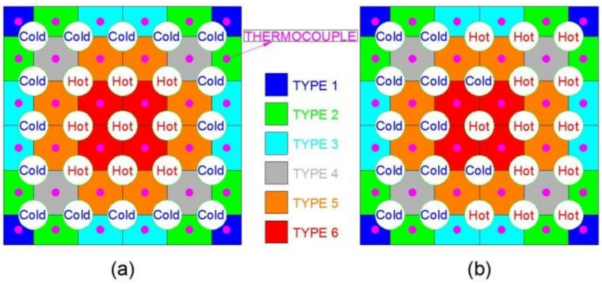

Fig. 1. The thermocouple location, configuration of hot and cold fuel rods and subchannel type color code

2.2 The determination of TDC

The TORC mixing evaluation was performed to determine each optimum TDC which is the smallest sum of $\Delta H (= H_p - H_c)$ for each test run in Fig. 2. It shows that the TDC for each test run was determined by minimizing the enthalpy differences between measurements and predictions by subchannel type based on the above ΔH equation in Fig. 2.

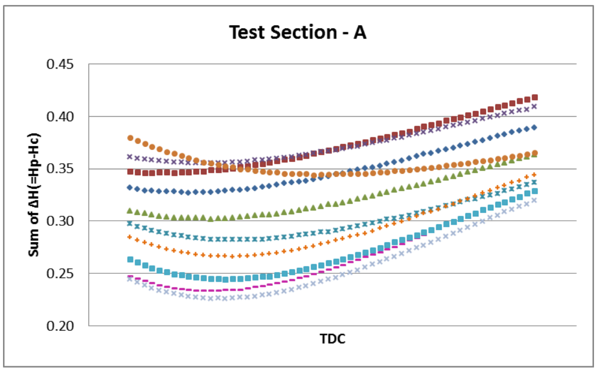

Fig. 2. The example how to determine TDC of Test Section - A

The best estimated TDC for the test was evaluated based on average TDC of all test runs.

2.3 The effect of mixing vane shape on TDC

It shows the difference of geometrical mixing vane shape below Fig. 3.

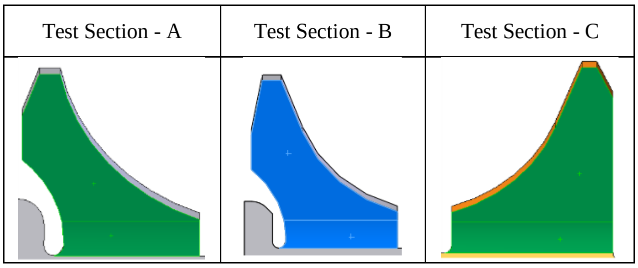

Fig. 3. The schematics of mixing vane shape

In order to check the effect of mixing vane shape on TDC, relative TDC of three different test sections which contain the same R-split type vane but the different design are presented in Table I with geometrical characteristics of test section. The relative TDC is to divide the TDC of each test section by the TDC of core design application. The standard deviation is not relative value but value itself.

Table I: The results of relative TDC

	Test Section - A	Test Section - B	Test Section - C
Relative TDC	1.463	1.482	1.645
Standard Deviation	0.0068	0.0084	0.0049
Power Ratio (Hot : Cold)	1 : 0.82	1 : 0.82	1 : 0.85
Rod Pitch [inch]	0.506	0.496	0.496
Rod O.D. [inch]	0.374	0.374	0.374
Rod to Wall Gap [inch]	0.102	0.122	0.100
Grid Span (center to center) [inch]	15.72	10.28	10.28

To be conservative, it is recommended that the TDC for data analysis exceeds the design TDC [2,3]. As a result, the TDC of all test sections exceeded the design TDC, regardless of mixing vane shape. The difference of each TDC is within 6% comparing the relative TDC (=1.553) which is used in CHF data analysis correlation and comes from grid span and characteristics of mixing vane shape.

3. Conclusions

The results come out reflecting their characteristics of test sections. TDC is predominately influenced by grid spacing and it would expect increased thermal mixing (higher TDC) with closer axial grid spacing. Also, the mixing vane shape (R-split type) makes TDC exceed design value. The data analysis results of TDC using subchannel code, TORC, showed that above TDC is higher than the design value. Therefore, the design TDC is conservative.

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ACKNOWLEDGMENT

This work is funded by the Korea Ministry of Knowledge Economy (R-2005-1-391), and the authors express their gratitude.