CHAPTER 5

OTHER ADAPTATIONS OF THE MODEL

5.1 Peripheral Non-Uniform Heating

Non-uniform heating along the circumference of the tube is of relevant importance in the thermal hydraulic design of fusion reactor. Some peripheral non-uniform heating experiments had been carried out. In Nariai et al experiment (1994), the non-uniform heating is reached by thinning a part of the tube wall. Figure 5-1 shows the cross section for the case of thinned part angle φ equals 90°, 180°, and 270° conditions. High heat flux is reached in thick wall part.

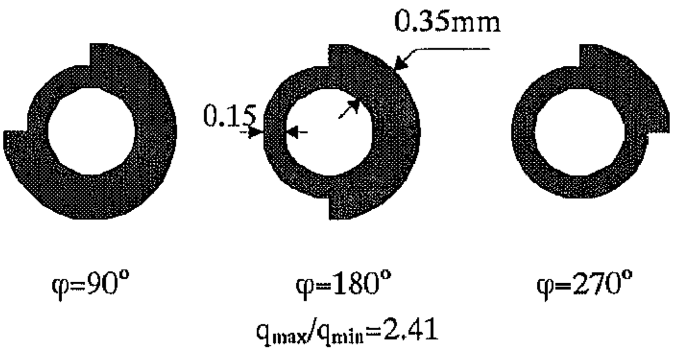

Fig.5-1 Peripheral Non-Uniform Heating
in the Nariai Experiment

The peripheral non-uniform heating CHF prediction can be accounted for simply in the present model by replacing the heat flux q in the calculation of the ΔT_d with the maximum value of the heat flux. Other calculations in which the heat flux is involved, such as in the calculation of ΔT_{lout}, χ_d and χ_{eqout}, are made by using the average heat flux. For the Nariai experiment, the average heat flux is calculated: $q_{avg} = 0.75q_{max}+0.25q_{min}$ for $\varphi = 90^\circ$, $q_{avg} = (q_{max}+q_{min})/2$ for $\varphi = 180^\circ$ and $q_{avg} = 0.25q_{max} + 0.75q_{min}$ for $\varphi = 270^\circ$. The CHF is the maximum value of the heat flux when burnout happens.

The CHF predictions for two kinds of condition are shown in figs.5-2 and 5-3 respectively. The solid and broken lines are the prediction results with employing the Chan-Prince and Harmathy correlation for drag coefficient respectively. The using of the Harmathy model shows a higher CHF prediction tendency than the using of the Chan-Prince model. Better CHF agreement is got with employing the Chan-Prince drag coefficient.

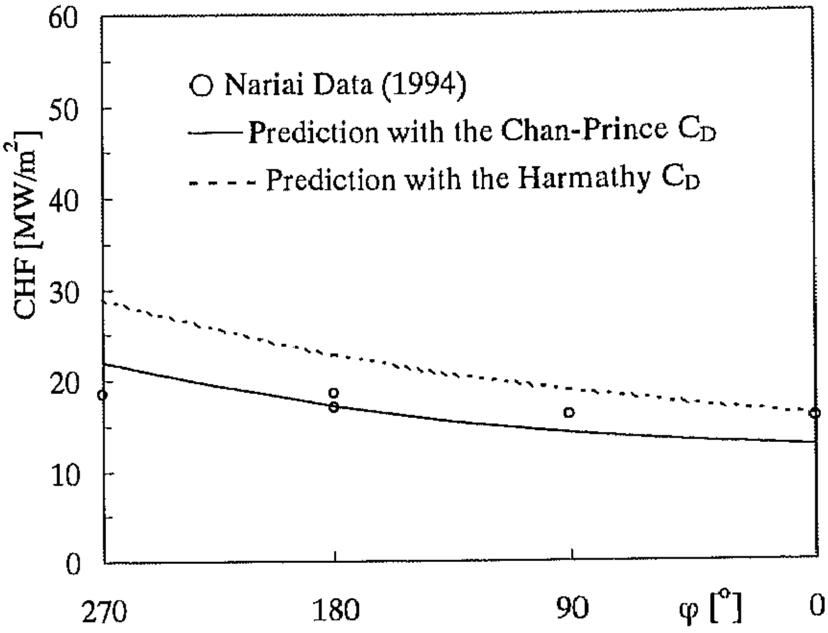

Fig.5-2 CHF Prediction for Peripheral Non-Uniform Heating at $G=4Mg/m^2s$, $P=1.1MPa$, $D=6mm$, $L=0.1m$, $T_{in}=40°C$

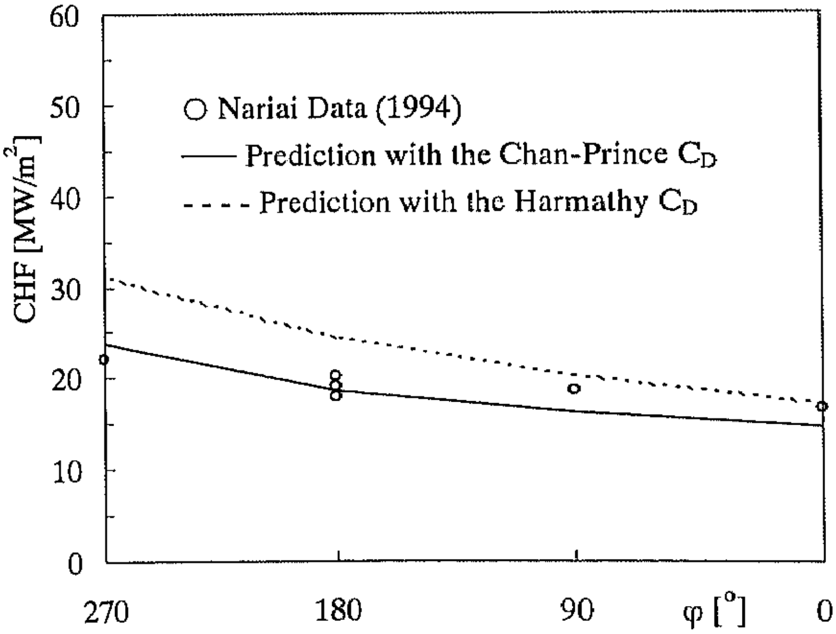

Fig.5-3 CHF Prediction for the Peripheral Non-Uniform Heating at $G=7Mg/m^2s$, $P=0.6MPa$, $D=6mm$, $L=0.1m$, $T_{in}=40°C$

5.2 Presence of Swirl Flow Promoters

Twist tape inserting (fig.5-4) provides a means of getting comparatively high CHF. Several correlations have been developed to account for the effect caused by the twist tape.

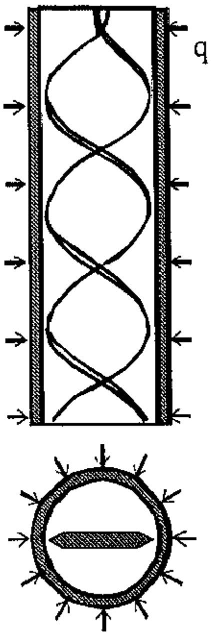

Fig.5-4 Twist Tape Insert Condition

As the presence of a twisted tape is associated with swirl flow, the liquid velocity along the flow is increased compared with axial velocity in straight tube. A resultant liquid velocity $V_{\gamma l}$ was suggested by Gambill (1961). The modification is written as:

$$V_{\gamma l} = V_l \left(4\gamma^2 + \pi^2\right)^{1/2} / (2\gamma) \qquad (5\text{-}1)$$

where γ is the twist ratio of the tape.

For the twisted tape gives no thermal change to the tube, the increase of the velocity can be seen as the effect of the increase of the mass velocity. The prediction is therefore accounted for by using multiple G with the same proportion as $V_{\gamma l}$ to V_l.

Figure 5-5 shows the model prediction for Nariai data (1991) that is characterized by the low mass velocity. Fig.5-6 shows the CHF prediction for the Nariai and the Gambill data (1961). The Gambill data is in the range of: G=15 ~ 40Mg/m^{2}s, D=4.6 ~10.2mm, L=0.063 ~ 0.4115m, T_{in}=9 ~ 60°C and γ from 2.08 to 4.95. The data is characterized by the high mass flux. The present model seems giving good prediction to the Nariai data and the high pressure Gambill data and shows loosing the adaptation to the low pressure--high mass flux data. The results imply that only using the Gambill modification may be not sufficient to characterize the twist tape effect under low-pressure high mass flux condition where the swirl flow effect is significant.

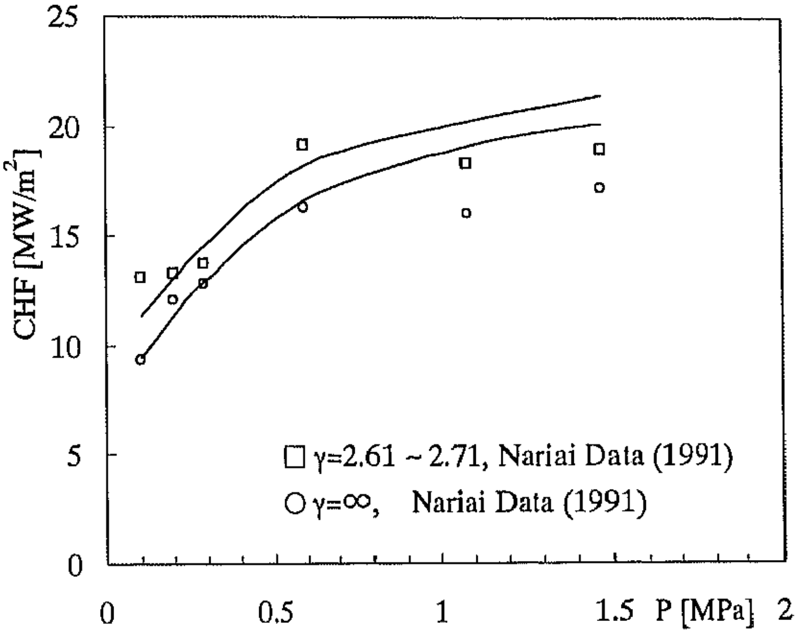

Fig.5-5 Twist Tape Inserts CHF Prediction for Nariai Experiment

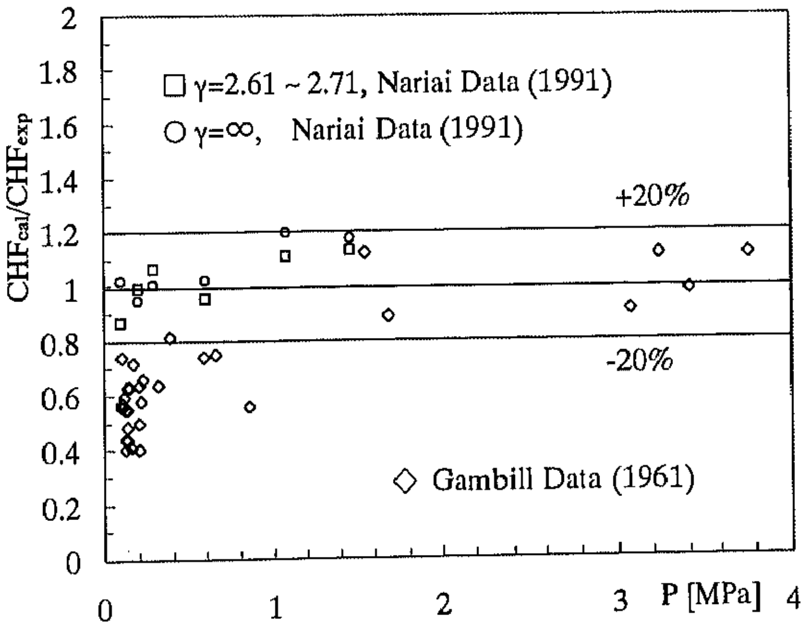

Fig.5-6 Twist Tape Inserts CHF Prediction for both the Nariai and Gambill Data

As we know, twist tape insert causes swirl flow. At low mass flux, this swirl flow effect is not significant and does not affect the near wall bubble blanket. The tape's effect can be seen as only increasing the axial velocity. The present model is so expected to be able to predict CHF with only the modification to the mass flux. Under such circumstance, the CHF enhancement effect should not be very significant. At high mass flux, the swirl flow may be significant and destroys the near-wall vapor blanket. The CHF enhancement effect is therefore expected to be significant. Because the present model with only the modification to the mass flux does not reveal the true CHF mechanism under such circumstance, the model looses rightness, giving too low CHF prediction, as shown in Fig.5-6.

With the increase of pressure, the vapor blanket diameter D_B and length L_B decrease significantly. Therefore it becomes difficult for the swirl flow to destroy the near wall vapor blanket. Under such circumstance, again, the model prediction turns possible and the CHF enhancement effect is not significant.

5.3 Presence of both the Swirl Flow Promoters and Peripheral Non-Uniform Heating

The present model is also adapted to the condition with the twist tape inserted in peripheral non-uniform heating tube. The prediction is accounted for by the simply assemble of the two solving ways for the peripheral non-uniform heating condition and twist tape insert condition. The result is shown in fig.5-7 with compared to the Nariai data (1994). The result is generally good.

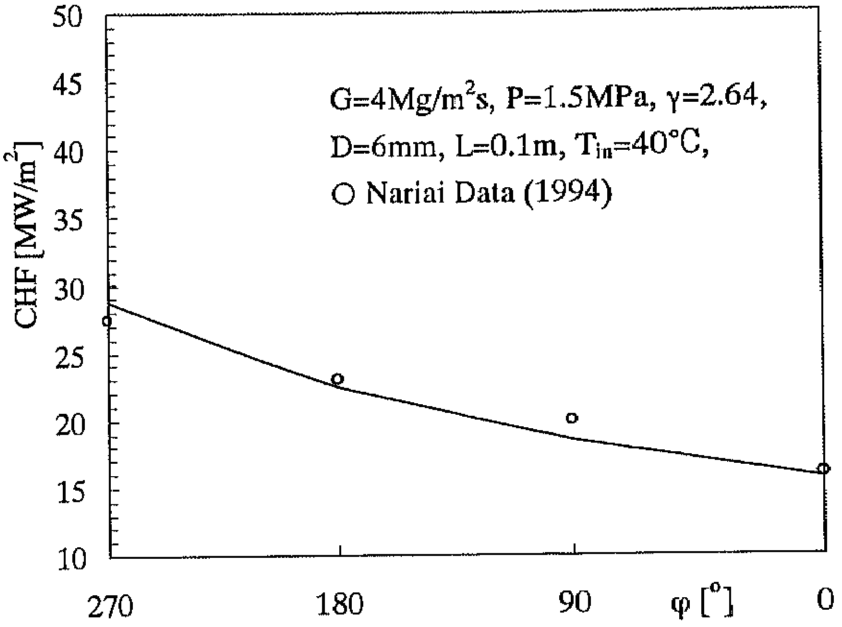

Fig.5-7 CHF Prediction for the both Emergences of the Twist Tape and the Peripheral Non-Uniform Heating Condition

5.4 Prediction of the CHF for Non-Water Fluids

If the proposed prediction approach is soundly based, it should be capable of providing reasonable CHF prediction not only for water, but also for fluids other than water. The proposed model is therefore compared with the experimental data that were obtained with refrigerant 113 and liquid nitrogen. The result is shown in Fig.5-8.

To evaluate ΔT_{lout} and χ_{out}, determination of the NVG point (ΔT_d) is very important. When water is used as coolant, as we have mentioned, generally, the Ahmad model is recommended. But because the Ahmad model is unable to be used for liquid nitrogen (whose enthalpy is a minus value) NVG point prediction, the Levy model (which has been tested adaptable for any kind of fluids) is used. In the R-113 CHF prediction, still the Ahmad model is adopted.

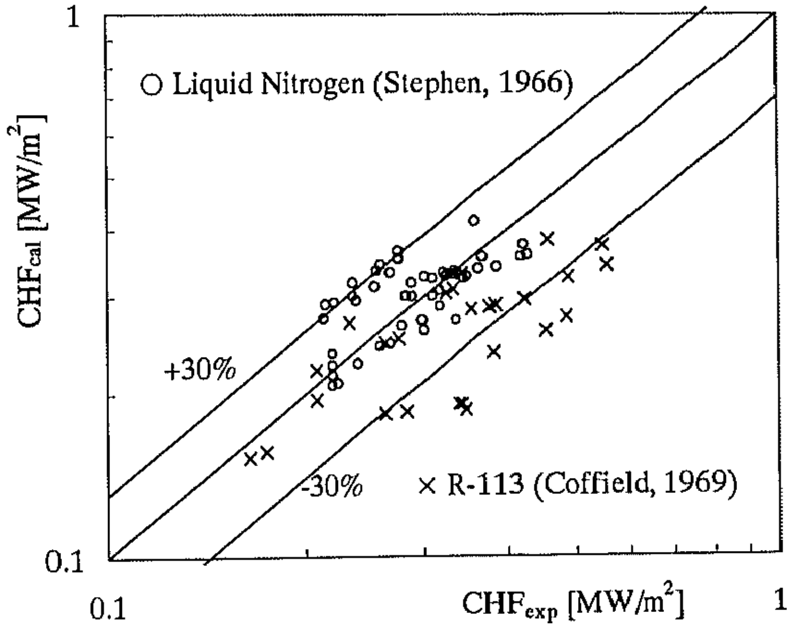

Fig.5-8 CHF Prediction for the Non-Water Fluids Condition