§42. Transient Critical Heat Fluxes of Subcooled Water Flow Boiling in SUS304-circular Tubes with Various Twisted-Tape Inserts (Influence of Twist Ratio)

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The influence of twist ratio on transient critical heat fluxes (transient CHFs) of subcooled water flow boiling in circular tubes with various twisted-tape inserts is necessary to investigate the reliability of a divertor in a nuclear fusion facility for short pulse high heat flux test mode.

The ratios of transient CHF data for the SUS304 test tube of d=6 mm with the twisted-tape of the twist ratio, y, of 2.40 on the wide exponential periods (91 points) to the corresponding values calculated by the steady-state CHF correlation against inlet subcooling for the test tubes with various twisted-tape inserts, Eq. (1), are shown versus the non-dimensional exponential period, p^*, in Fig. 1 [1,2]. The ratios are almost constant for the p^* greater than around 1500 and equivalent to around 0.8, and those become higher with the decrease in non-dimensional exponential period from around 1500. And the values of the transient CHF almost become two times as large as the steady-state ones at the non-dimensional exponential period of 57.8. The curves given by the transient CHF correlation against inlet subcooling for the test tubes with various twisted-tape inserts, Eq. (2), are shown in Fig. 1 for comparison. The trend of a decrease in transient CHF data with an increase in the non-dimensional exponential period for the wide range of the non-dimensional exponential periods is almost in good agreement with the values given by Eq. (2).

$$Bo_{cr,sw} = C_1 D^{*-0.1} We_{sw}^{-0.3} \left(\frac{L}{d}\right)^{-0.1} e^{-\frac{(L/d)}{C_2 Re_d^{0.4}}} Sc^{*C_3} \quad (1)$$

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Figure 2 shows the influence of swirl velocity on the transient CHF for the SUS304 test tube of d=6 mm with the twisted-tape of the twist ratio, y, of 2.40 with exponentially increasing heat inputs of τ=40 ms, 165 ms and 8 s at inlet subcooling, $\Delta T_{sub,in}$, of around 150 K [1,2]. The $q_{cr,sub}$ for the swirl velocities, u_{sw}, of 6.13, 10.71, 15.3 and 20.7 m/s were shown versus the u_{sw} with the exponential period, τ, as a parameter. The values of the transient CHFs obtained from Eq. (2) are also shown as solid curve in Fig. 2 for comparison. The transient CHFs become higher with an increase in the u_{sw} at a fixed exponential period. The slopes of each curve on the $\log q_{cr,sub}$-$\log u_{sw}$ graph become almost constant and equivalent to around 0.44 at τ=8 s in the figure. Those become lower with the decrease in the exponential period like 0.34 at τ=165 ms and 0.23 at τ=40 ms. At a low flow velocity, the time-lag of the formation of the transient CHF for the increasing rate of the heat input would greatly become bigger to grow the temperature profile in the conductive sub-layer on the test tube surface for thicker conductive sub-layer.

Figure 3 shows the influence of twist ratio of twisted-tape on the transient CHF for the SUS304 test tubes of d=6 mm with the twisted-tapes of the twist ratios, y, of 2.40, 3.37 and 4.45 with exponentially increasing heat inputs of τ=40 ms, 165 ms and 8 s at inlet subcooling, $\Delta T_{sub,in}$, of around 150 K [1-3]. The $q_{cr,sub}$ for the swirl velocities, u_{sw}, of 15.2, 13.4 and 12.5 m/s were shown versus the y with the exponential period, τ, as a parameter, not for a fixed u_{sw}. The values of the transient CHFs obtained from Eq. (2) with the swirl velocities, u_{sw}, of 15.2, 13.4 and 12.5 m/s are also shown as solid curve in Fig. 3 for comparison. The transient CHFs become gradually lower with an increase in the y at a fixed exponential period. The decreasing rate of each curve on the log-log graph becomes almost constant around 7.6 % for the y ranging from 2.4 to 4.45 in the figure. However, that is equivalent to the decreasing rate of the transient CHFs 7.5 % for the swirl velocity decreasing from 15.2 m/s to 12.5 m/s, that is to say, it has been reported that the CHFs are proportional to $u^{0.4}$ in the whole range of the flow velocity [4]. It is supposed from this fact that the twist ratio of the twisted-tape has not exerted a strong influence on the transient CHFs, although the swirl velocity has done.

The ratios of transient CHF data for the SUS304 test tubes of d=6 mm and L=59.4 mm (L/d=9.9) with the twisted-tapes of the twist ratios, y, of 2.40, 3.37 and 4.45 to the values calculated from the transient CHF correlation against inlet subcooling for the test tubes with various twisted-tape inserts, Eq. (2), are shown versus the p^* at the inlet pressures of 743.70 to 994.07 kPa in Fig. 4 [1-3]. This correlation can describe the transient CHF data for the SUS304-tubes with the twisted-tape of the twist ratios, y, of 2.40, 3.37 and 4.45 (186 points) for the wide range of the non-dimensional exponential periods (p^*=48.21 to 5.044×10^4) and the swirl velocities (u_{sw}=5.07 to 20.70 m/s) at $\Delta T_{sub,in}$=around 150 K within -26.19 to 9.81 % difference as shown in Fig. 4.

1) Hata, K., et al., Proceedings of ICONE21-15323 (2013) 1-13. 2) Hata, K., et al., *Journal of Thermal Science and Engineering Applications*, **6** (2014) 031010-1-14. 3) Hata, K., et al., *Journal of Power and Energy Systems*, **7** No. 2 (2013) 122-137. 4) Hata, K., and Masuzaki, S., *Nuclear Engineering and Design*, **240** (2010) 3145-3157.

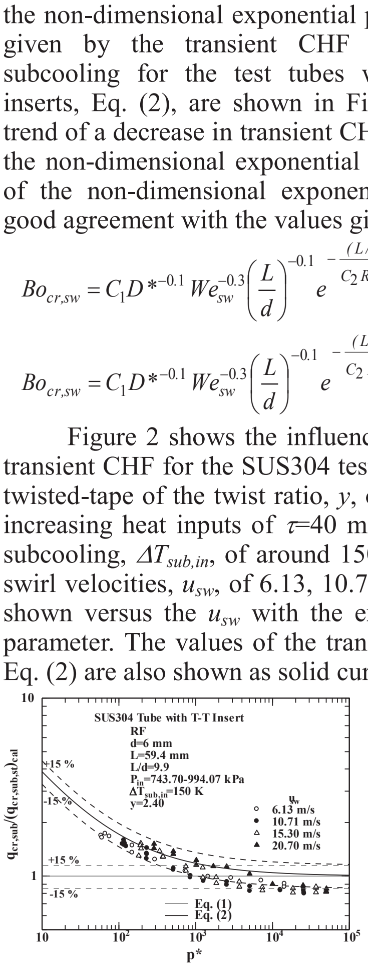

Fig. 1 Ratios of $q_{cr,sub}$ for d=6 mm with y=2.40 (91 pnts) to values calculated by Eq. (1) vs. p^*

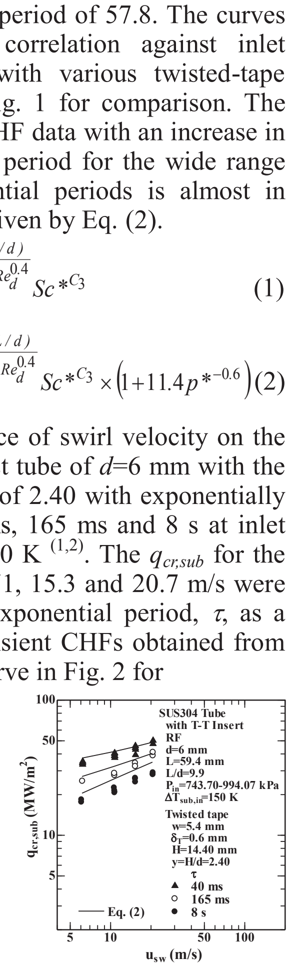

Fig. 2 $q_{cr,sub}$ vs. u_{sw} for d=6 mm with y=2.40 on τ=40 ms, 165 ms and 8 s at $\Delta T_{sub,in}$=150 K

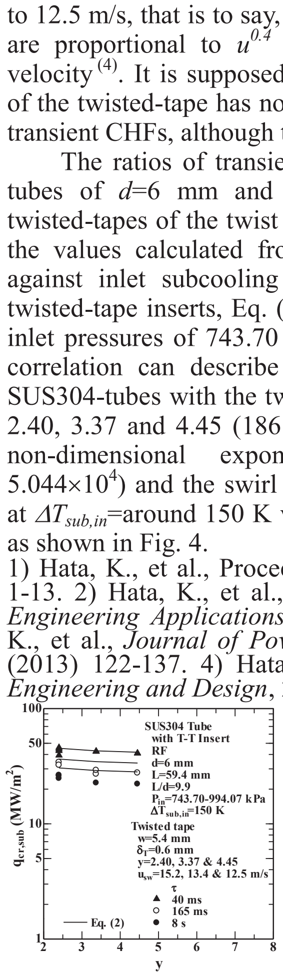

Fig. 3 $q_{cr,sub}$ vs. y for d=6 mm with y=2.40, 3.37 and 4.45 on τ=40 ms, 165 ms and 8 s at $\Delta T_{sub,in}$=150 K

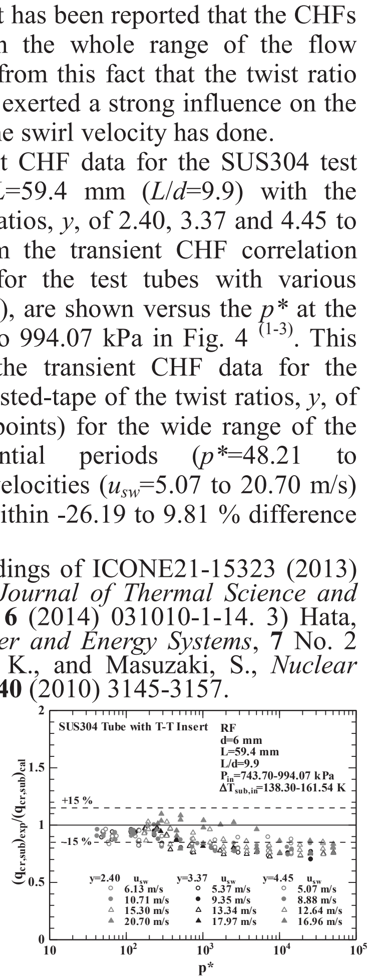

Fig. 4 Ratios of $q_{cr,sub}$ for d=6 mm with y=2.40, 3.37 and 4.45 (186 pnts) to values calculated by Eq. (2) vs. p^*