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Numerical study of heat transfer characteristics of downward supercritical kerosene flow inside circular tubes

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Numerical Model

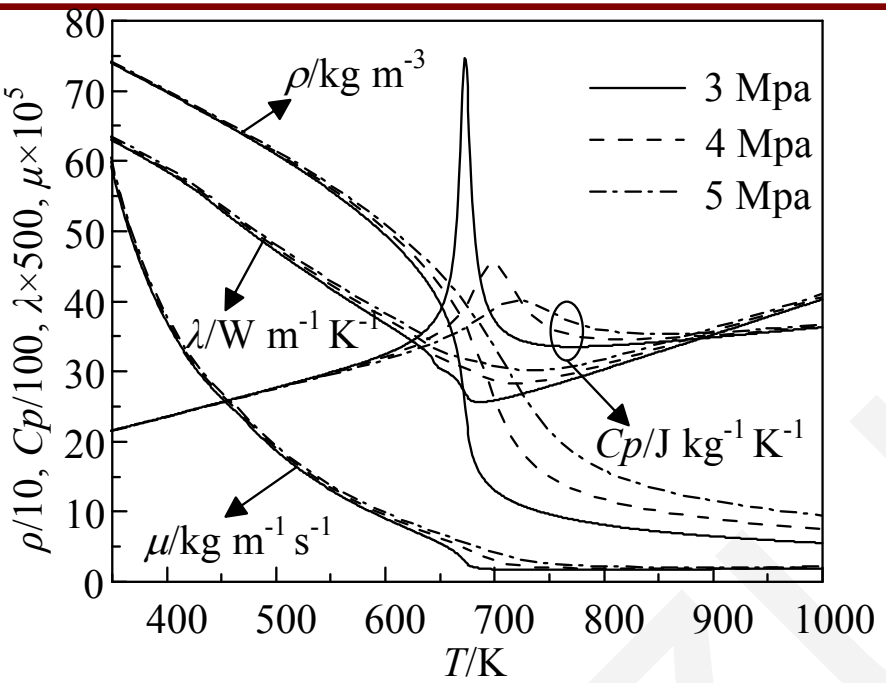


Fig. 1. Thermophysical properties of China RP-3 aviation kerosene

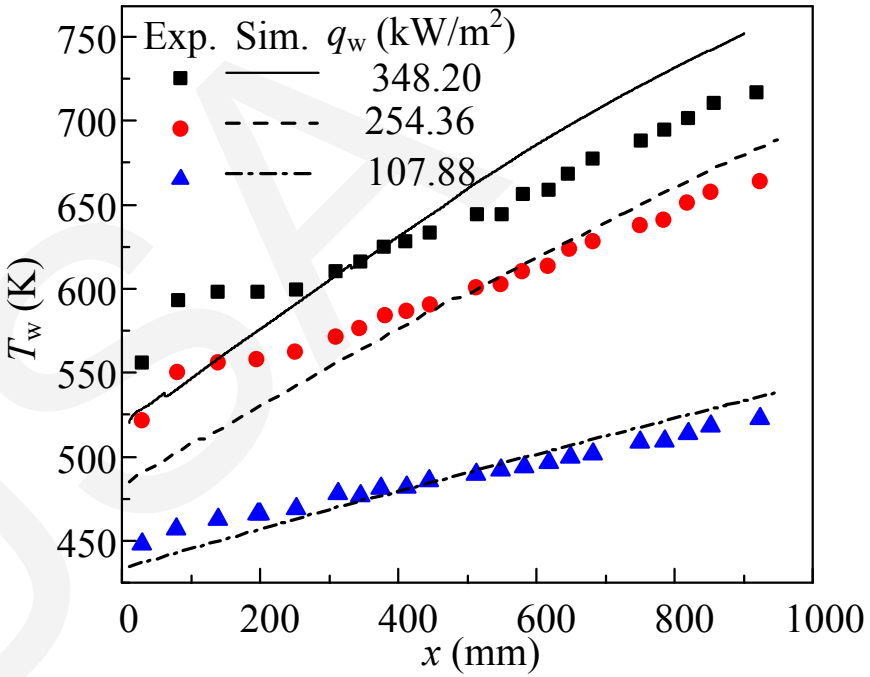


Fig. 2. Comparison between numerical results and experimental data

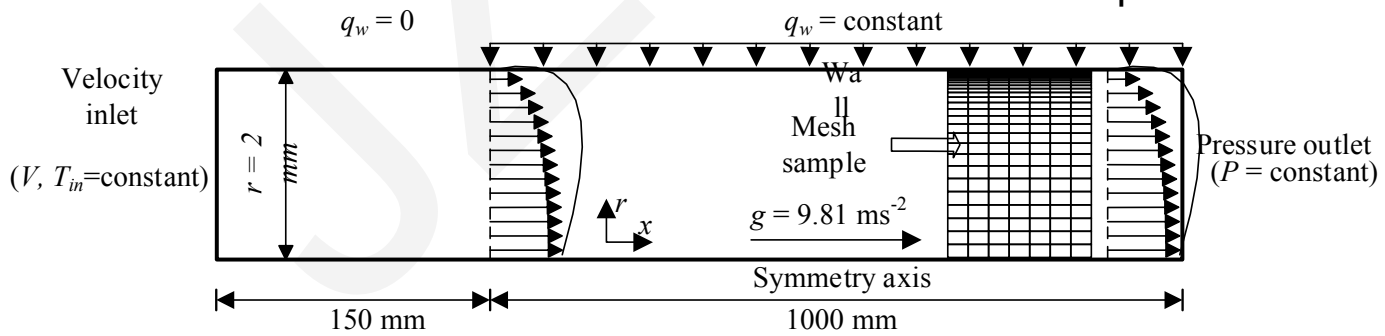


Fig. 3. Schematic of the computational configuration

Heat Transfer Deteriorations

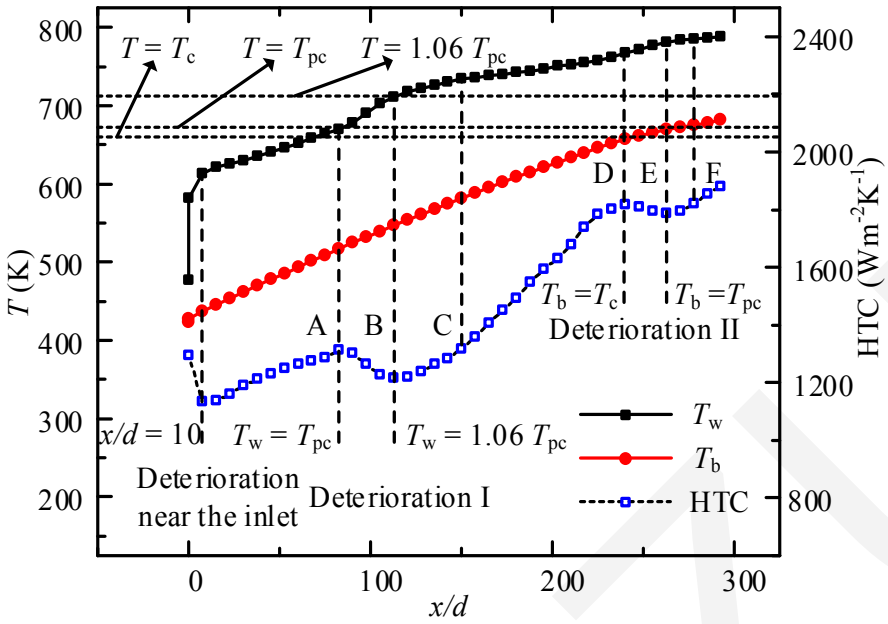


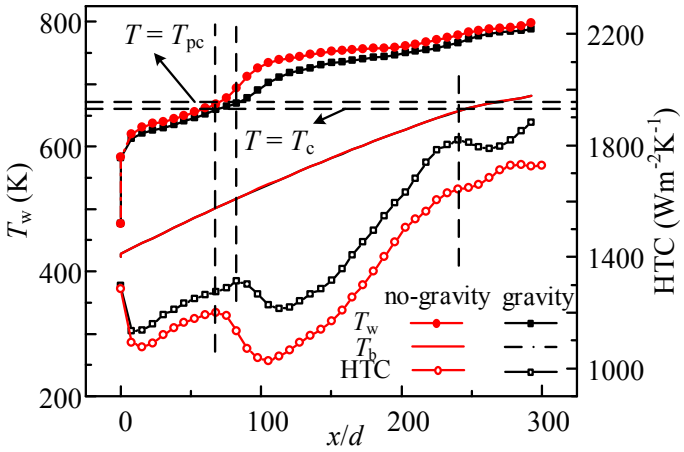
Fig. 4. The wall temperature (Tw), liquid bulk tem-perature (Tb), and heat transfer coefficient (HTC) distri-butions along the tube axial direction

1. Three types of heat transfer deteriorations were observed in the downward supercritical flow.

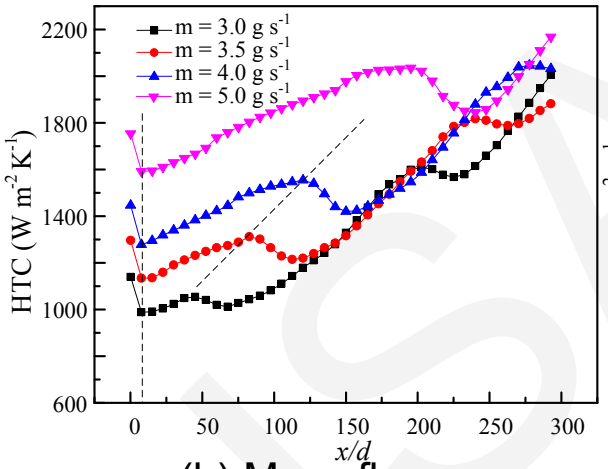
2. The first type of deterioration is caused by the development of the thermal boundary layer and exists at the entrance of the tube within x/d = 10.

3. The second and third types of deterioration appear when the wall or bulk fuel temperature approaches the pseudo-critical temperature. Drastic variations of the kerosene properties and the concurrent thermal acceleration effect in the near-wall region are the main reasons for the second type of deterioration.

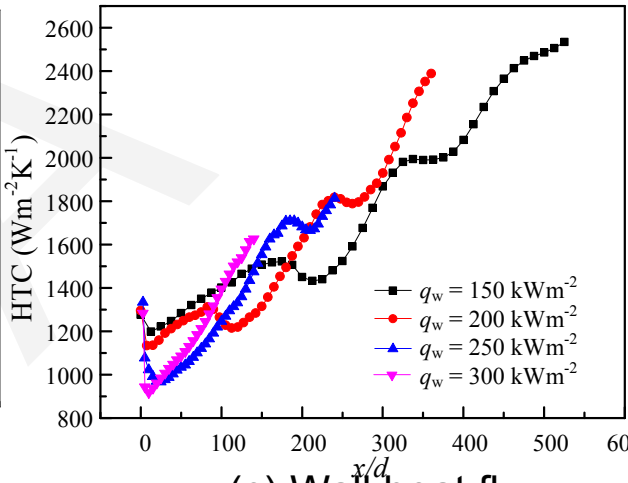
Heat Transfer Deteriorations



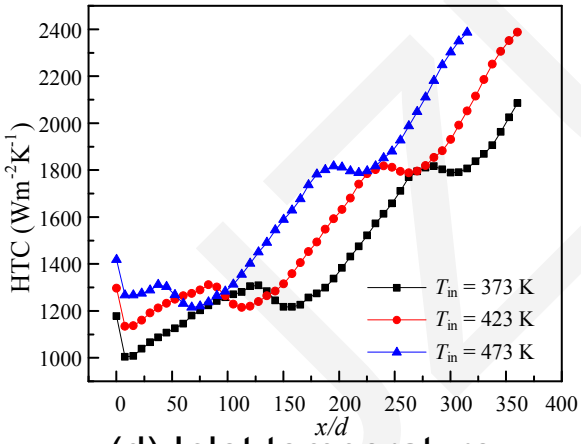
(a) Gravity



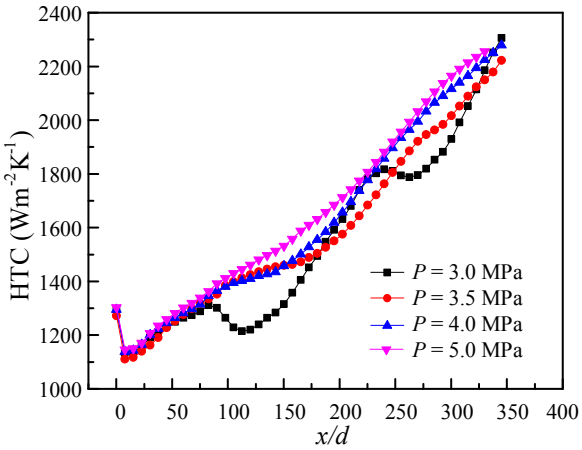
(b) Mass flux



(c) Wall heat flux



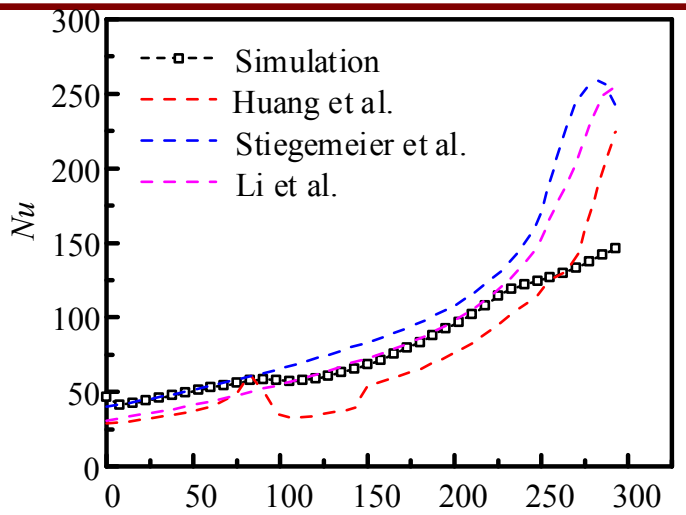
(d) Inlet temperature

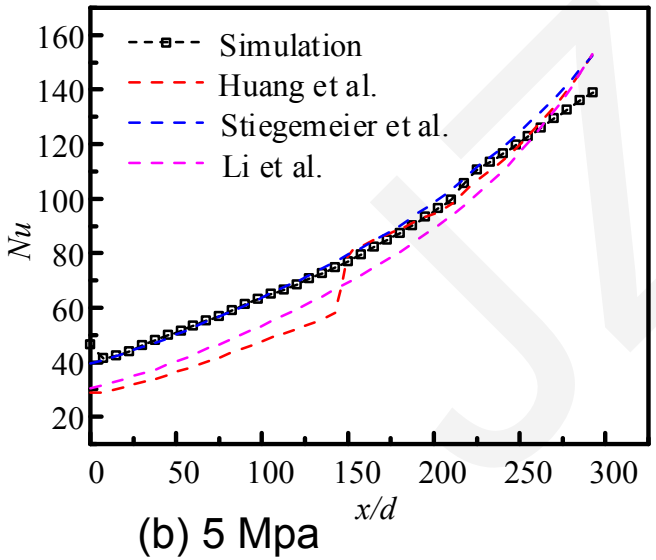


(e) Inlet pressure

Fig. 5. Effects of gravity, mass flux, wall heat flux, inlet temperature, and inlet pressure on HTC

Comparisons with empirical correlations





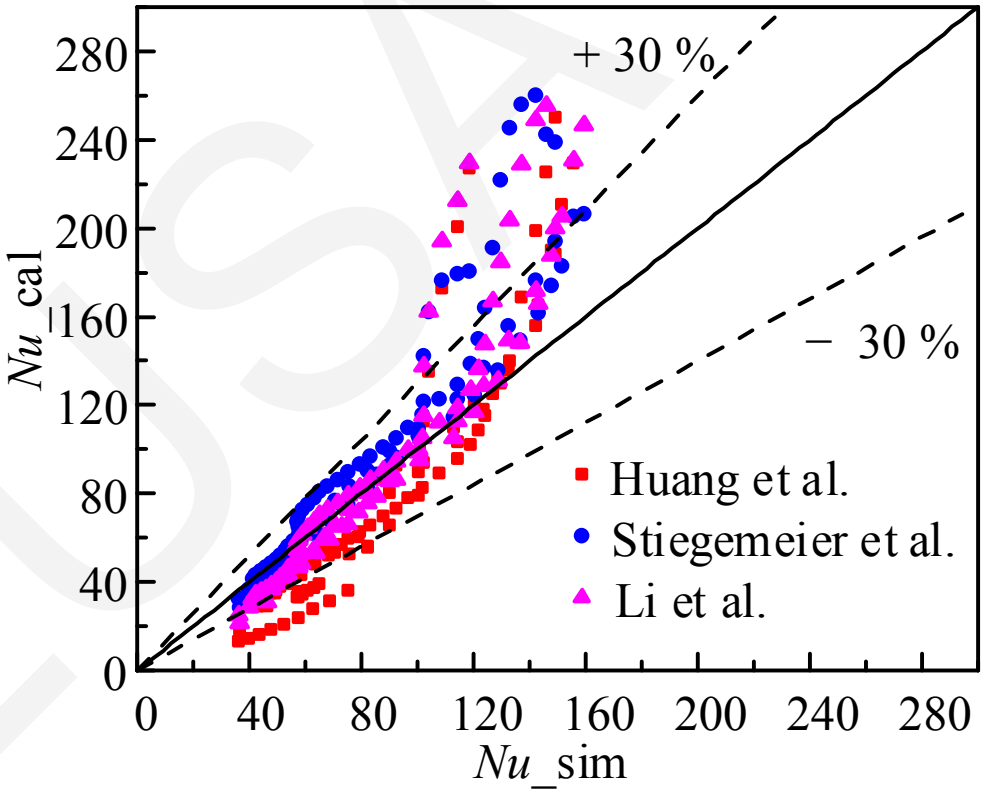


Fig. 6. Comparison of Nu between simulation and empirical correlations

Conclusions

1. The mass flow rate has no effect on the end of Deterioration near the inlet, while a higher mass flow rate delays the onsets of Deterioration I and Deterioration
2. The onsets of Deterioration I and Deterioration II are delayed along the tube axial direction under lower qw, while the deterioration is more pronounced at a higher wall heat flux.
3. The inlet temperature only affects the starting point of the heat transfer process.
4. The effect of P on Deterioration near the inlet is negligible. Deterioration I and Deterioration II are not observed for the cases with P higher than 3 MPa because of the more moderate variations of properties of kerosene under higher pressures.