Towards the evaluation of heat and mass transfer in pipe flows with cocurrent falling films using One-Dimensional Turbulence

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The process engineering branch of air-liquid system applications is vast and comprises relevant topics of research ranging from the influence of (liquid) surface wave dynamics, to classical laminar and turbulent flow dynamics concerning heat and mass transfer. Seminal works such as those of Yan et al. [1], and Feddauoi et al. [2] have already ellucidated important issues in the physical interactions between momentum, mass, and heat transfer of air-water systems. For such systems, an industrial application of practical relevance is the falling film evaporator. Heat and mass transfer related issues in this device are mainly concerned with the evaporative cooling of the liquid falling film, and the potential component concentration increase in the liquid. Direct Numerical Simulations (DNSs) of falling films are mostly focused on the immediate surroundings of the film. The transition dynamics of the (inner) gas stream, particularly for turbulent flows, and the effect that such dynamics could have on the interfacial shear stress at the liquid film, is an issue that should be addressed by DNS investigations. However, to the best of our knowledge, no DNS has yet been able to address a dynamically similar case to that of a full falling film evaporator. In the meanwhile, this study could be the first stepping stone to bridge the DNS gap utilizing a stochastic turbulence model which allows full scale resolution in a reduced dimensional setting, in comparison to traditional filter-based turbulence models. We use a novel numerical solver implementing the One-Dimensional Turbulence (ODT) model [3] in a cylindrical turbulent heated air flow which is surrounded by a laminar cocurrent water falling film. The solver utilizes the ODT model in order to evaluate the effects of turbulent advection and turbulent heat flux in the (inner) gas side, while the liquid side is assumed laminar. The simulation results are compared to the numerical Reynolds-Averaged Navier-Stokes (RANS) study performed by [2] for a cocurrent water falling film evaporator.

References

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[3] W. T. Ashurst and A. R. Kerstein, Phys. Fluids **17**(2) (2005) 025107.