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Investigation on Heat Transfer Behaviour of Supercritical Nitrogen

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Extended Abstract

A fluid above its critical temperature and pressure (P_c, T_c) is called supercritical (SCF) under which conditions the distinction between liquid and gas phases no longer exists. Due to the varied intra-molecular bonds, SCFs possess unique thermodynamic properties that are significantly different from their ambient state leading to different behavioural profiles and opening up a wide range of applications especially in the domains of energy production, environment protection and green processes. They become green solvents for extraction, particle production and superior reaction media for a wide range of catalytic and non-catalytic reactions. The products of SCF-mediated processes are of highly improved quality (in terms of purity and production efficiency), and process economic feasibility.

Supercritical nitrogen (SCN_2) is frequently used in in energy-related chemical engineering technologies such as air separation. Recently developed cryogenic energy storage technology uses liquid air/nitrogen as both energy storage carrier and heat transfer fluid [1, 2]. However, SCN_2 has the great advantages of enhanced heat transfer properties namely heat transfer coefficient and thermal conductivity, which greatly impacts the specific heat capacity.

As nitrogen transfers from subcritical (compressed) to supercritical state, it experiences extreme variation of the above thermodynamic properties, creating highly rapid impact on the system behaviour. The objective of this study is to assess the influence of key parameters (heat flux, mass flux) on the heat transfer behaviour in supercritical nitrogen in the large specific heat region by employing the k-ε turbulence model. More specifically this work represents a qualitative analysis of the heat transfer coefficient trend in supercritical nitrogen flowing vertically up in a 2 mm diameter tube, at a working pressure of 3.6 MPa, for mass fluxes 300, 600, 900 kg/(m2s), and heat flux from 11450 to 120000 W/m2.

The simulations are conducted in 2D axis-symmetric, steady state, using the pressure-based solver in ANSYS Fluent.

The results obtained highlight the heat transfer deterioration with increasing heat flux, while the Dittus-Boelter correlation for the *Nu* number is used as reference.

For all mass and heat fluxes investigated the heat transfer coefficient trend shows a sharp increase with bulk temperature, reaching a peak near the pseudo-critical point after which there is a significant drop in values. Moreover, the magnitude of the heat transfer coefficient in the large specific region is proportional to the mass flow rate.

The well-known Dittus-Boelter correlation over predicts the values around the pseudo-critical point where the extreme variation of thermo-physical properties becomes important.

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References

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