Abstract

„The impact of the boiling process of cryogenic liquids on their regasification process"

Because of the ongoing climate crisis, the necessity arose to seek a transitional fuel that would help to reduce carbon dioxide emissions while striving for zero-emissivity. Natural gas has been proposed as such a fuel, primarily due to its lower global warming potential compared to other fossil fuels and its technological maturity. Although there are inhibitions regarding the extension of worldwide reliance on fossil fuels, the undeniable historical rise in the importance of this gas in the global energy landscape is evident.

Prior to the utilization of LNG as an energy source, the fuel must be regasified. The objective of this thesis is the theoretical and experimental analysis of the regasification process of cryogenic liquid, along with freezing risk mitigation of the heating fluid and determination of the film boiling process impact on the overall regasification process.

This objective was achieved by conducting theoretical and experimental studies of two types of heat exchangers for mobile applications: a shell-and-tube heat exchanger used in maritime transport systems and a helical coil heat exchanger dedicated to road transport. Given the need to prevent uncontrolled ice layer formation on the heating agent side, which in the case of experimental studies was water, the boiling of the cryogenic agent took place in the film boiling region, characterized by low heat transfer coefficients. The heat exchanger was designed for the regasification of LNG, but liquid nitrogen was chosen as the working fluid due to its properties: it is non-corrosive, relatively inexpensive, chemically inert, readily available, non-flammable, and presents no additional hazards apart from the standard properties

of a cryogenic liquid at low temperature.

It was demonstrated that film boiling generates the greatest thermal resistance during the regasification process and thus has the most significant impact on the overall heat exchange process between the cryogen and the heating fluid. Therefore, the application of an appropriate mathematical model describing the boiling process is crucial, yet the film boiling region has not been fully understood and theoretically described due to occurring flow instabilities and lack of thermodynamic equilibrium between the phases.

An original, two-dimensional mathematical model of the helical coil heat exchanger was developed, in which commonly used expressions for calculating criterial numbers in the context of film boiling, tube flow, and heat conduction coefficients through the helical wall and ice layer were implemented. The developed models were validated through experimental results, changes were proposed to existing models describing film boiling under forced flow at cryogenic temperatures, and the location of ice buildup on the spiral at high enough mass flow rates of the regasified cryogen was determined, which was also confirmed experimentally.