ABSTRACT

„ The impact of freezing of a heating medium on cryogenic liquid regasification"

Natural gas (NG) is considered as the cleanest fossil fuel. Its liquefied form, LNG (Liquefied Natural Gas), is primarily produced for long-distance transport and more efficient storage purposes. Nevertheless, significance of a natural gas in energy markets is growing also within the context of usage LNG as a possible fuel for power generation, industry and transportation systems.

The final stage in technological processes that involve LNG, is its vaporization and heating to ambient temperature. This process is most commonly achieved using plate or shell-and-tube heat exchangers, with water or water-glycol mixture as the heating medium. However, low boiling temperature of cryogenic liquids poses a risk of the heating medium freezing, which can lead to the damage of the heat exchanger and all other equipment. For this reason, there is a need for a better understanding of the process and the parameters that determine it.

The research area in the submitted doctoral dissertation encompasses the modeling of heat and flow phenomena that take place in a heat exchangers or its considered part, with particular emphasis on heat transfer between cryogenic liquid and the heating medium. The main objective of the dissertation was to develop a numerical model in the field of Computational Fluid Dynamics (CFD), designed for multifaceted conceptual calculations supporting the heat exchanger design process, analyzing its performance under specific conditions, as well as facilitating specific actions in case of a failure.

As a part of the dissertation, a simplified model of cryogens boiling was proposed and developed. The main point is to represent and treat a cryogen as a solid body with adjusted thermal conductivity. This model was applied to calculations in all stages of the research. In the initial phase, the model underwent validation on a simplified flow geometry through a rectangular channel, where the obtained values of the ice layer thickness on the heating medium side were compared with an analytical solution. In subsequent steps, the influence of various parameters, such as boiling conditions of the cryogenic fluid, as well as the temperature and velocity of the heating medium was examined.

The next stage of the research involved analyzing the heating medium flow around the tubes, considered here as a fragment of a shell-and-tube heat exchanger. Within these analyses, numerical tests were conducted to investigate the impact of the shape of the tubes on the formation of the ice layer was investigated. The collected results allowed for comparisons on several fronts, such as heat power and pump efficiency.

The final form of both verification and analysis was to perform computation on a full-scale model of a shell-and-tube heat exchanger, and compare the obtained results with the experimental data. Here, the model was enriched with a part corresponding to the superheating of cryogen vapor after evaporation. Moreover, still focusing on the freezing possibility of the heating medium, a failure scenario was considered, where the flow of water is stopped and then resumed after a certain period. This was checked to determine whether, in such a situation, ice would block the entire exchanger and whether it would be possible to resume its operation after such a temporary interruption.

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