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Numerical Validation of Liquid Nitrogen Phase Change in a Star-Shaped Ambient Vaporizer

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Abstract : Gas Nitrogen where has a boiling point of -189.52oC at atmospheric pressure widely used in the industry. Nitrogen that used in the industry should be transported in liquid form to the plant area. Ambient air vaporizer (AAV) generally used for vaporization of cryogenic gases such as liquid nitrogen (LN2), liquid oxygen (LOX), liquid natural gas (LNG), and liquid argon (LAR) etc. AAV is a group of star-shaped fin vaporizer. The design and the effect of the shape of fins of the vaporizer is one of the most important criteria for the performance of the vaporizer. In this study, the performance of AAV working with liquid nitrogen was analyzed numerically in a star-shaped aluminum finned pipe. The numerical analysis is performed in order to investigate the heat capacity of the vaporizer per meter pipe length. By this way, the vaporizer capacity can be predicted for the industrial applications. In order to achieve the validation of the numerical solution, the experimental setup is constructed. The setup includes a liquid nitrogen tank with a pressure of 9 bar. The star-shaped aluminum finned tube vaporizer is connected to the LN2 tank. The inlet and the outlet pressure and temperatures of the LN2 of the vaporizer are measured. The mass flow rate of the LN2 is also measured and collected. The comparison of the numerical solution is performed by these measured data. The ambient conditions of the experiment are given as boundary conditions to the numerical model. The surface tension and contact angle have a significant effect on the boiling of liquid nitrogen. Average heat transfer coefficient including convective and nucleated boiling components should be obtained for liquid nitrogen saturated flow boiling in the finned tube. Fluent CFD module is used to simulate the numerical solution. The turbulent k-ε model is taken to simulate the liquid nitrogen flow. The phase change is simulated by using the evaporation-condensation approach used with user-defined functions (UDF). The comparison of the numerical and experimental results will be shared in this study. Besides, the performance capacity of the star-shaped finned pipe vaporizer will be calculated in this study. Based on this numerical analysis, the performance of the vaporizer per unit length can be predicted for the industrial applications and the suitable pipe length of the vaporizer can be found for the special cases.

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