Methods (cont'd)

\[ f_L = \frac{64}{Re_L} + \frac{0.3164}{Re_L^{0.25}} \]

[for \( Re_L \geq 1187 \)]

\[ f_v = \frac{f_L}{\left( \frac{\rho_v}{\rho_l} \right)^{0.125} \left( \frac{\mu_v}{\mu_l} \right)^{0.25}} \]

results for \( Re_L \geq 74 \) and \( Re_L \geq 1187 \)

where \( \mu \) is the dynamic viscosity (kg/ms).

For a rough linear increase of frictional pressure drop with increasing quality of \( x \), this can be written as:

\[ \Gamma = A + (B - A)x \]

\[ \Delta p_{friction} = \frac{\rho L G^2 \phi^2}{2d} \]

The frictional pressure drop is converted into frictional pressure gradients by dividing by the length of the tube.

Results and Discussion (cont'd)

To validate the correlations by Muller-Heck and Souza-Pimenta, a simulation of refrigerant R-134a flowing through a 10.92 mm diameter circular tube is compared with experimental data from Ould-Didi et al. as seen in Figure 1 [4]. The mass velocity, \( G \), is set to 300 kg/ms at a saturation temperature of \( T_{sat} = 4 \) °C.

Results and Discussion

Abstract

The use of minichannel technology to improve the thermal efficiency of solar thermal collectors has been demonstrated by our group with test data obtained from aluminum minichannel solar water heater tested throughout a year [1]. A second phase of this project intends to study the performance of minichannel collectors operating at medium temperatures with the purpose of generating steam. Due to the increased temperature, copper minichannel tubes have been selected for the construction of the solar collector. This poster presents preliminary simulations of two-phase pressure drop predictions in copper minichannel tubes. Two pressure drop correlations were used for comparison: 1. Muller-Steinhagen and Heck; and 2. Souza and Pimenta. The model is first validated against experimental data for refrigerant R134a. Then the model is used to predict pressure drop inside copper minichannel tubes using water as the working fluid. This is a first step for our final goal simulating two-phase flow phenomena in minichannel solar thermal collectors. The construction of the collector is currently underway.

Introduction

Our group is currently working on the design of a copper minichannel solar thermal collector for the purpose of steam generation at temperatures slightly above 100 °C. From our results of our previous work on aluminum minichannel solar water heater, we observed that it is possible to reach saturation temperatures for water [1]. However, due to yield strength limitations of aluminum at medium temperatures we are developing a copper minichannel solar thermal collector.

Having the ability to predict two-phase heat transfer and pressure drop in the copper min!channel tubes enables us to accurately design and optimize an efficient solar collector.

The objective of this poster is to predict two-phase pressure drop in copper minichannel tubes at operating conditions typical of a solar thermal collector.

Methods

The mathematical model of calculating the two-phase pressure drop using Muller-Heck and Souza-Pimenta correlations are described in [2, 3]. Those correlations were implemented in Engineering Equation Solver (EES) to simulate and calculate the two-phase pressure drops at given saturation temperature for a range of inlet qualities and mass fluxes of the fluid [5]. The first set of simulations assumed flow inside a circular pipe using R-134a refrigerant as the working fluid with the purpose of validation against experimental results found in [4]. After validation, the mathematical models was applied to copper minichannel tubes with two-phase water mixtures as the working fluid at typical conditions that would be used in solar collector experiments.

Mathematical Model

Muller-Steinhagen & Heck’s Friction Pressure Drop Correlation:

The two-phase friction pressure drop correlation by Souza and Pimenta utilizes properties of the liquid and vapor phase. As a two-phase multiplier and Lockhart-Martelli’s parameter [3]. The two-phase multiplier is similar to Chisholm (1968, 1973, 1983) with some variation:

\[ \phi^2 = 1 + (p - 1)\phi \frac{G}{\rho l} \frac{1}{\gamma} \frac{\chi}{\gamma_2} \]

where \( y \) is a physical property index, and \( \chi \) is Lockhart-Martelli’s parameter:

\[ \chi = \frac{\phi}{\rho_l} \frac{\mu_l}{\mu_v} \frac{\gamma_2}{\gamma_1} \frac{1}{\gamma_2} \frac{1}{x} \]

In the equations above, \( \mu \) represents the dynamic viscosity (kg/ms), and \( v \) is the specific volume (m³/kg).

The frictional pressure drop is known represented by:

\[ \Delta p_{friction} = \frac{\rho L G^2 \phi^2}{2d} \]

Conclusion

Simulation and validation of the two-phase pressure drop correlations by Muller-Heck and Souza-Pimenta are shown. Souza-Pimenta’s correlation to a circular pipe compared to experimental data shows a reasonable fit. However when both correlations are fitted for a copper minichannel tube, significant differences in pressure drop are obtained. More analysis needs to be performed.

Future work includes finding a better fit for approximating two-phase pressure drop especially for minichannel tubes and validating against experimental data that utilizes minichannel tubes; developing a model for calculating boiling heat transfer coefficient; running experiments and collecting data with the copper minichannel solar thermal collector.

References

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