PREDICTION OF TWO-PHASE PRESSURE DROP IN HEAT EXCHANGER FOR MIXED REFRIGERANT JOULE-THOMSON CRYOCOOLER

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Work station
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Exchanger
J-T Valve
Evaporator
Bye-pass
valve
Suction
valve
Compressor
Oil filters
Aftercooler
Rotameter
Heat
Exchanger
J-T Valve
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valve
Suction
valve
Compressor
Oil filters
Aftercooler

REF To

REFERENCES


PREDICTION OF TWO-PHASE PRESSURE DROP IN HEAT EXCHANGER FOR MIXED REFRIGERANT JOULE-THOMSON CRYOCOOLER

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MOTIVATION

- Recuperative heat exchanger governs the overall performance of mixed refrigerant Joule-Thomson (MR J-T) cryocooler.
- Need of accurate predictive tools for pressure drop to design the heat exchanger for the efficient operation of the cryocooler.
- Limited experimental data is available, related to pressure drop of mixed refrigerants of nitrogen-hydrocarbons at cryogenic temperatures.
- There is no generalized correlation for two-phase frictional pressure drop in the literature, which is applicable to a wide range of working fluids, mass velocities, pressures and channel diameters.

OBJECTIVE

- To evaluate the existing empirical correlations for prediction of two-phase frictional pressure drop in the recuperative heat exchanger for MR J-T cryocooler.

TWO-PHASE FRICTIONAL PRESSURE DROP CORRELATIONS

Total pressure drop \( \Delta P_{\text{total}} = \Delta P_{\text{frict}} + \Delta P_{\text{frict\_2}} + \Delta P_{\text{g}} \), where \( \Delta P_{\text{frict}} \) is a two-phase friction factor, \( \Delta P_{\text{frict\_2}} \) is mass velocity, \( L \) is length, \( d_h \) is hydraulic diameter, and \( \rho \) is two-phase density.

Homogeneous Flow Model (HFM)

Two-phase frictional pressure drop, \( \Delta P_{\text{frict}} \), is expressed by the following equations:

- Two-phase frictional multiplier, \( \delta \):
  \[ \delta = \frac{1}{2} \left( 1 + \frac{f_{\text{frict}}}{f_{\text{frict\_2}}} \right) \]

- Lockhart-Martinelli correlation [14]:
  \[ \delta = 1 - \frac{1}{\frac{f_{\text{frict}}}{f_{\text{frict\_2}}}} \left( 1 - \frac{f_{\text{frict}}}{f_{\text{frict\_2}}} \right) \]

- Where coefficient \( C \) varies between 0 to 20 depending on flow regime.

Separated Flow Model (SFM)

Frictional pressure drop correlations based on SFM.

Muller-Steinhagen and Heck correlation (1986):

\[ \frac{\Delta P_{\text{frict}}}{\Delta P_{\text{frict\_2}}} = \frac{\mu_{\text{eff}}}{\mu_{\text{ref}}} = \left( \frac{12}{\kappa} \right)^{1/2} \]

Sami and Duong correlation (1992):

\[ \frac{\Delta P_{\text{frict}}}{\Delta P_{\text{frict\_2}}} = \left( \frac{12}{\kappa} \right)^{1/2} \left( 1 + \frac{1}{2} f_{\text{frict}} \right) \]

Zhang et al. correlation (2010):

\[ \frac{\Delta P_{\text{frict}}}{\Delta P_{\text{frict\_2}}} = \left( \frac{12}{\kappa} \right)^{1/2} \left( 1 + \frac{1}{2} f_{\text{frict}} + \frac{1}{4} f_{\text{frict}}^2 \right) \]

Comparison between predicted and experimental two-phase frictional pressure drop

EXPERIMENTAL SET-UP

Helically coiled tube-in-tube heat exchanger

Specifications of Heat Exchanger [7]

Parameter
Value
Inner tube ID (mm) 4.83
OD (mm) 6.35
Outer tube ID (mm) 7.89
OD (mm) 9.52
Length of heat exchanger (m) 15
Coil diameter (mm) 200

RESULTS AND DISCUSSIONS

CONCLUSIONS

- Experiments are carried out to measure two-phase pressure drop in the evaporating stream of MR J-T heat exchanger for two different mixture compositions.
- Extensive evaluation of the existing two-phase frictional pressure drop correlations is presented.
- The Zhang et al. [26] and Kim and Mudawar [27] correlation which are developed for micro-channels based on SFM give the best predictions of the pressure drop data within 30% error limit among 15 different correlations assessed.