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Theoretical Evaluation of Minimum Superheat, Energy and Exergy in a High-Temperature Heat Pump System Operating with Low GWP Refrigerants

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Abstract : Suitable low global warming potential (GWP) refrigerants that conform to F-gas regulations are required to extend the operational envelope of high-temperature heat pumps (HTHPs) used for industrial waste heat recovery processes. The thermophysical properties and characteristics of these working fluids need to be assessed to provide a comprehensive understanding of operational effectiveness in HTHP applications. This paper presents the results of a theoretical simulation to investigate a range of low-GWP refrigerants and their suitability to supersede refrigerants HFC-245fa and HFC-365mfc. A steady-state thermodynamic model of a single-stage HTHP with an internal heat exchanger (IHX) was developed to assess system cycle characteristics at temperature ranges between 50 to 80 °C heat source and 90 to 150 °C heat sink. A practical approach to maximize the operational efficiency was examined to determine the effects of regulating minimum superheat within the process and subsequent influence on energetic and exergetic efficiencies. A comprehensive map of minimum superheat across the HTHP operating variables were used to assess specific tipping points in performance at 30 and 70 K temperature lifts. Based on initial results, the refrigerants HCFO-1233zd(E) and HFO-1336mzz(Z) were found to be closely aligned matches for refrigerants HFC-245fa and HFC-365mfc. The overall results show effective performance for HCFO-1233zd(E) occurs between 5-7 K minimum superheat, and HFO-1336mzz(Z) between 18-21 K dependant on temperature lift. This work provides a method to optimize refrigerant selection based on operational indicators to maximize overall HTHPs system performance.

Keywords : high-temperature heat pump, minimum superheat, energy & exergy efficiency, low GWP refrigerants
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