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Performance Evaluation of Ejector Based CO_2 System for Simultaneous Heating and Cooling Application in an Indian Dairy Industry

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ABSTRACT

India is ranked first in milk production, and its goal is to increase annual production to 300 million tons by 2024. The dairy industry requires multi-temperature cooling and simultaneous heating. In the present study, the ejector based transcritical CO_2 system with two evaporators (LT at -10°C, MT at 0°C) is analyzed and proposed for fulfilling both cooling and heating demands in the dairy industry. Ejector based systems with and without internal heat exchanger are analyzed and compared. The effects of gas cooler outlet temperature, receiver pressure and gas cooler pressure on the performance of the system are investigated by energy and exergy analysis. The gas cooler pressure is analyzed for achieving the desired pasteurization temperature. The internal heat exchanger not only reduces the minimum gas cooler pressure required for the pasteurization temperature but also increases the system COP and exergy efficiency by 6.4% and 4.5% respectively. Second law analysis shows that the maximum exergy efficiency of the system is 38.4%.

Keywords: Trans-critical; Internal heat exchanger; Pasteurization; Exergy analysis; pressure optimization.

1. Introduction

Carbon dioxide was a widespread refrigerant in the early 18th century, which was used in the form of dry ice but was phased out with the invention of synthetic refrigerants. In 1985 Roland and Molina found that the use of halocarbon refrigerants causes the destruction of the ozone layer [1]. This, together with global warming, led to the search for alternate refrigerants. CO_2 being a natural refrigerant with zero ODP and GWP of 1, is conceived to be the best alternate refrigerant, especially for heat pump applications where simultaneous heating and cooling loads are in demand [2]. The operational pressure of CO_2 is higher than that of conventional refrigerants, making it a highly challenging refrigerant. However, 20% of energy saving is achieved for the same heating capacity and temperature requirement when compared with R12 [3].

At high ambient temperature CO_2 system works in the transcritical cycle. Therefore the maximum irreversibility occurs in throttling the gas. To minimize the loss during the expansion process and to utilize the available energy, researchers have proposed the use of ejectors. It is a simple device without any moving parts. A recent experimental study on a multi ejector pack reported a maximum work recovery efficiency of 36% [4]. Thermodynamic analysis of the CO_2 transcritical cycle [5] showed that the use of an ejector enhances the COP by 16%. Deng et al. [6] reported that the maximum cooling COP for the ejector expansion system is 8.2% and 11.5% higher than that of the internal heat exchanger cycle and conventional refrigeration cycle respectively. Fangtian and Yitai [7] reported that the ejector improves the COP by 30% and reduces the exergy loss by 25% when compared with the expansion valve.