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Thermodynamic Analysis of Modified Vapour Compression Refrigeration System using R-134a

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Abstract

The performance analysis of a modified vapour compression refrigeration system has been carried out in this paper based on energy and exergy analysis and compared with the combined effect of two separate systems. The system is modified combining two conventional systems through a heat exchanger. Heat exchanger in the modified system acts as a condenser in the secondary loop and super heater in the primary loop. A computational model has been developed in EES using energy and exergy equations to calculate different parameters for evaluating the system performance. Simulation results show that modified system gives better result compared to separate systems.

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Keywords: MVCR; Exergy; COP; Compressor work; Exergetic efficiency; Heat exchanger; R-134a

1. Introduction

The Montreal Protocol (1987), the London (1990) and Copenhagen amendments (1992) scheduled the ban of production of CFCs by the end of 1995 and of HCFCs by 2030 [1]. Hence, HC and HFC based refrigerants are taken into consideration due to their zero ODP and significantly low GWP. This fact encouraged researchers to replace R-12 by R-134a on a short term basis as it has very similar thermodynamic properties [2]. Theoretical study on an actual vapour compression refrigeration system by Chen and Prasad [3] using R134a and CFC12 as refrigerants showed that COP of the system using refrigerant R134a was 3% lower than that with CFC12. They also found that

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compressor power requirement as well as exergy loss of the system increased when R134a was used compared to CFC12. Kim and Kim [4] numerically and experimentally investigated an auto cascade refrigeration system using R744/134a and R744/290 as refrigerants. They found that refrigeration effect, COP of the system decreased whereas compressor power increased when the inlet temperature of the secondary heat transfer fluid increased. They also found that cooling capacity and compressor power increased with the increase in mass fraction of R744, but COP decreased. A numerical and experimental investigation was carried out by Kilicarslan [5] on different type of two-stage vapour compression cascade refrigeration system using R134 as the refrigerant. He found higher COP in case of cascade system than that for the single stage system. Soni and Gupta [6] presented a theoretical study on the performance of a vapour compression refrigeration system using R407C and R410A as refrigerants based on energy and exergy analysis. They found that the COP and EE of the system with R-407C was better than that with R-410A. Pottker and Hrnjak [7] presented an experimental study on effect of condenser subcooling on the performance of air conditioning system using two refrigerants, R134a and R1234yf, under the same operating conditions. They concluded that the COP of the system improved more due to condenser subcooling when the system work with refrigerant R1234yf compared to that of R134a. In another study, Pottker and Hrnjak [8] conducted a theoretical study on the effect of condenser subcooling on vapour compression refrigeration system. They reported that with the increase in condenser subcooling, system gave better COP value due to the increase in refrigeration effect. Qureshi et al. [9] experimented on a residential vapour compression refrigeration system employing a dedicated mechanical subcooling cycle with it and the performance was compared with and without dedicated cycle performance. It was noted that load carrying capacity of the cycle increased when dedicated system was used. It was also reported that the second-law efficiency of the cycle was increased by 21% when dedicated system was employed. In this present study, the authors propose a new modified system which improves COP and analyze performance of the system thermodynamically for different working conditions.

Nomenclature

COP	Coefficient of Performance	ED	Exergy Destruction
EDR	Exergy Destruction Ratio	EE	Exergetic Efficiency
EF	Exergy of Fuel	EP	Exergy of Product
EX	Exergy at corresponding points	GWP	Global Warming Potential
h	Enthalpies at corresponding points	ODP	Ozone Depletion Potential
$\dot{Q}$	Rate of heat transfer	RE	Refrigeration Effect
s	Entropies at corresponding points	$\dot{m}_1$	Mass Flow Rate in Primary Cycle
$\dot{m}_2$	Mass Flow Rate in Secondary Cycle	Q_{11}	Heat absorbed in primary evaporator
T_0	Dead State Temperature	T_C	Condenser Temperature
T_{EVA1}	Evaporator Temperature in Primary Cycle	T_{EVA2}	Evaporator Temperature in Secondary Cycle
T_{HX}	Heat Exchanger Temperature	T_r	Reference Temperature
T_{SH}	Degree of Superheating	W_C	Compressor Work
η_{ex}	Exergetic Efficiency	ε	Effectiveness of Heat Exchanger

2. Cycle Description

The modified system is developed combining two conventional vapour compression cycles together with a heat exchanger. Secondary cycle is connected with the primary cycle with that heat exchanger. In that modified system, heat exchanger acts like a condenser in the secondary cycle and as a superheater in the primary cycle. Schematic diagram of the proposed system has been shown in figure 1. The system components include two evaporators, two compressors, one condenser, two expansion valves and one heat exchanger. Both the evaporators are placed in the location where temperature to be maintained low. In the secondary cycle, evaporator takes the heat from that location and refrigerant evaporated and enters into the compressor. Vapour refrigerant is then compressed to a higher pressure and temperature where the heat exchanger is placed. In the heat exchanger, that refrigerant exchanges heat