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Thermodynamic analysis of vapour compression refrigeration system with mixing of Al_2O_3Nano material in fourteen ecofriendly refrigerants

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Abstract

The most commonly-used method for analysis of an energy-conversion process is the first law of thermodynamics. But in the recent decades, the exergetic performance based on the second law of thermodynamics has found as useful method in the design, evaluation, optimization and improvement of vapour compression refrigeration systems. The exergetic performance analysis can not only determine magnitudes, location and causes of irreversibility in the vapour compression refrigeration systems. But also provides more meaningful assessment of power plant individual components efficiency. Using concept of exergy, a thermal model for vapour compression refrigeration system using nano refrigerants was developed and numerical computation was carried out by using Al2O3 mixed in fourteen ecofriendly refrigerants and found that thermodynamic performances in terms of first law efficiency, exergetic efficiency /second law efficiency increased significantly.

Keywords: Thermodynamic performances, Energy-exergy Analysis, Eco friendly refrigerants, Nano- materials.

1. Introduction

The second law analysis (i.e. exergy Computation) is widely accepted as a useful tool for obtaining overall performances of any system for finding various exergy losses occurred in its components Exergy analysis also helps in taking account the important engineering decisions regarding design parameters of a system by finding maximum exergy destruction using entropy generation principle. A conventional exergetic analysis reveals irreversibility within each component of a vapour compression refrigeration systems. Exergetic analysis provides the tool for a clear distinction between energy losses to the environment and internal irreversibility in the process because exergy analysis is a methodology for the evaluation of the performance of devices and processes, and examining the exergy at different points in a series of energy-conversion steps. With this information, efficiencies can be evaluated, and the process steps having the largest losses (i.e., the greatest margin for improvement) can be identified. For these reasons, the modern approach uses the exergy analysis in the vapour compression refrigeration systems, which provides a more realistic view of the process and a useful tool for engineering evaluation

Many researchers have carried out exergy studies of different thermal energy conversion systems describing various approach for exergy analysis and its usefulness for improving existing designs by reducing exergy destruction in a more simple and effective manner [1]. Yumrutas et. al [2] investigated of the effects of the evaporating and condensing temperatures on the pressure losses, exergy losses, second law of efficiency, and the COP of a vapour compression cycle. Dincer [3] asserts that conventional energy analysis, based on the first law of thermodynamics, evaluates energy mainly on its quantity but analysis that are based on second law considers not only the quality of energy, but also quantity of energy.. Nikolaidis and Probert [4] used exergy method for calculating ting thermodynamic performances of R22 in a two-stage compound compression cycle, with flash intercooling. Bejan [5] developed, thermodynamic model by using heat transfer irreversibility and showed that the exergetic efficiency decreases as evaporator temperature decreases. Sajadi A.R. et.al. [6] experimentally investigated turbulent convective heat transfer coefficient and pressure

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drop of TiO_2 dispersed in water nano fluid in the circular tube and also compared experimental results with correlation of Nusselt number and not concluded that how much (%) convective heat transfer coefficient increased. Huang Dan, et.al. [7], observed the effect of hybrid nano fluid mixture Al_2O_3 in the plate heat exchanger and found that convective heat transfer coefficient is increased as compared without nano fluid. Zeinali S Heris et.al [8] experimentally investigated the convective heat transfer increment in the laminar flow forced convection heat transfer due to increase in the thermal conductivity of nano fluid due to nano particle fluctuations present in that fluid The above investigators have not studied in detail regarding performances of the vapour compression refrigeration systems in which nano refrigerants was circulated in the whole system. Therefore present investigation take care the overall system thermal performances in terms of first law efficiency (COP) and second law efficiency/ exergetic efficiency and various efficiencies of compressor used in the system.

2. Result and Discussion

2.1 Variation of Evaporator and condenser temperature on thermal performances by mixing TiO_2 nano particles

Table-1 shows the performance of vapour compression refrigeration system using fourteen ecofriendly (alternate) refrigerants mixed with Al_2O_3. It was found that refrigerants R134a R404a and R507a give similar trends in their first law efficiency (COP), second law efficiency, exergetic efficiency and exergy destruction ratio, compressor efficiency, isentropic efficiency and volumetric efficiency with slightly variations. Similarly R1234yf and R125 and R600a gives similar trends with slightly variation, however lower than R134a. The best performances were found using R290 hydrocarbon and R407c which is higher than R134a. The worst performances were found by using R410a, R236fa, and super worst first and second law performances were observed by using Al_2O_3 mixed in R245fa, R123 refrigerants. Table-2 shows the variation of thermal performance with varying evaporator temperature. It is found that first law efficiency (COP) increases with increasing evaporator temperature, In case of ,second law efficiency and exergetic efficiency, it is found that exergetic efficiency is increases with increasing evaporator temperature up to a certain temperature where exergetic efficiency, second law efficiency becomes optimum(i.e. maximum) and then started decreases with increasing evaporator temperature, the optimum value of evaporator temperature is found to be 274K (i.e. 1°C) while in case of optimum second law efficiency, the evaporator temperature to be 271K (i.e -2 °C). Similarly exergy destruction ratio which is a ratio of total exergy destruction Exergy (Losses in the system was sum of exergy destruction in components to the exergy of fuel or exergy of product) was evaluated based on exergy of fuel (i.e. total electrical power required for running compressor) and also EDR was evaluated based on exergy of product (i.e. effective utilization of cooling load) was decreasing while increasing evaporator temperature. The Isentropic compressor efficiency and volumetric efficiency is also increases with increasing evaporator temperature and it has optimum value at 274K (i.e. 1°C). Similarly Table-3 shows the variation of thermal performance with varying condenser temperature. It is found that first law efficiency (COP) decreases with decreasing condenser temperature, In case of second law efficiency and exergetic efficiency, it is found that exergetic efficiency is decreases with increasing condenser temperature. Similarly isentropic efficiency and volumetric efficiency decreases by increasing condenser temperature while exergy destruction ratio is also increases with increasing condenser temperature

Table-1: Variation of COP with evaporator temperature of Vapour compression usingAl_2O_3 nano materials in ecofriendly for condenser temp=48 ^0C & evaporator temperature=-5^0C

Refrg.	COP	EDR	Rational EDR	Exergetic Efficiency	Pressure Ratio (r_P)	Compressor Efficiency	Isentropic Efficiency	Volumetric Efficiency	Second Law Efficiency
R134a	4.36	1.659	0.6239	0.3761	6.032	0.8378	0.6339	0.5938	0.4860
R404a	4.316	1.694	0.6288	0.3712	5.003	0.8793	0.7321	0.6274	0.4831
R1234yf	4.004	1.976	0.6640	0.3360	5.475	0.8520	0.6992	0.6052	0.4479
R1234ze	3.836	2.150	0.6826	0.3174	6.129	0.8283	0.6183	0.5860	0.4294
R227ea	3.147	3.162	0.7597	0.2403	6.328	0.8157	0.5813	0.5758	0.3527
R407c	4.736	1.391	0.5818	0.4182	5.737	0.8514	0.6730	0.6067	0.5301
R507a	4.328	1.685	0.6275	0.3725	4.939	0.8818	0.7355	0.6293	0.4844
R125	4.044	1.935	0.6593	0.3407	4.97	0.8788	0.7339	0.6269	0.4527
R290	4.826	1.335	0.5718	0.4282	4.73	0.8835	0.7456	0.6308	0.5403
R600a	4.009	1.963	0.6632	0.3368	5.759	0.8411	0.6705	0.5964	0.4088
R152a	5.164	1.143	0.5334	0.4666	5.968	0.8465	0.6434	0.6008	0.5786
R32	6.952	0.5008	0.3337	0.6663	5.086	0.9008	0.7273	0.6447	0.7783
R410a	2.14	6.836	0.8727	0.1276	5.043	0.8924	0.7299	0.6379	0.2396
R236fa	1.812	9.998	0.9091	0.09093	7.426	0.7761	0.2031	0.5438	0.2029

Table- 2: Variation of thermal performances (First law efficiency (COP) and Exergetic efficiency) with variation of evaporator temperature using Al_2O_3 mixed R134a for condenser temp=48 ^0C.

Evaporator Temperature (K)	COP	EDR	Rational EDR	Exergetic Efficiency	Pressure Ratio (r_p)	Isentropic compressor Efficiency	Volumetric Efficiency	ED_Ratio	Second law Efficiency
263	2.182	5.356	0.8427	0.1573	7.319	0.7966	0.2567	0.7096	0.2904
268	4.36	1.659	0.6239	0.3761	6.032	0.8378	0.6399	0.512	0.488
270	4.87	1.492	0.5987	0.4013	5.596	0.8519	0.688	0.495	0.505
271	5.095	1.451	0.5920	0.4080	5.392	0.8585	0.7061	0.4924	0.5076
272	5.309	1.428	0.5881	0.4119	5.198	0.8648	0.7308	0.4925	0.5075
273	5.517	1.418	0.5864	0.4136	5.012	0.8709	0.7316	0.4948	0.5052
274	5.724	1.417	0.5862	0.4138	4.834	0.8767	0.7408	0.4986	0.5014
275	5.932	1.424	0.5875	0.4125	4.664	0.8823	0.7485	0.5038	0.4962
276	6.146	1.438	0.5898	0.4102	4.501	0.8876	0.7550	0.5101	0.4899
277	6.366	1.458	0.5932	0.4068	4.345	0.8927	0.7608	0.5174	0.4826
278	6.595	1.484	0.5975	0.4025	4.196	0.8976	0.7659	0.5256	0.4744
283	7.932	1.722	0.6326	0.3674	3.538	0.9194	0.7859	0.5796	0.4204

Table- 3: Variation of thermal performance (First law efficiency (COP) and Exergetic efficiency) with variation of Condenser temperature using Al_2O_3 mixed R134a for evaporator temp=268 K

Condenser Temperature (K)	COP	EDR	Rational EDR	Exergetic Efficiency	Pressure Ratio (r_p)	Isentropic Compressor Efficiency	Volumetric Efficiency	ED_Ratio	Second law Efficiency
328	2.373	5.507	0.8463	0.1537	7.182	0.8017	0.319	0.7344	0.2656
323	3.88	2.102	0.6776	0.3224	6.375	0.8279	0.5777	0.5657	0.4343
318	5.017	1.224	0.5503	0.4497	5.584	0.8520	0.6891	0.4383	0.5617
313	6.096	0.7531	0.4297	0.5704	4.893	0.8742	0.7379	0.3176	0.6824
308	7.358	0.405	0.2882	0.7118	4.269	0.8944	0.7634	0.1763	0.8237

3. Conclusion

Following conclusions were drawn while using Al_2O_3 in the ecofriendly refrigerants.

- The first law efficiency (COP) increases with increasing evaporator temperature
- The exergetic efficiency is increases with increasing evaporator temperature up to a certain temperature where exergetic efficiency, second law efficiency becomes optimum (i.e. maximum) and then started decreases with increasing evaporator temperature.
- The optimum value of evaporator temperature is found to be 274K (i.e. 1ºC) while in case of optimum second law efficiency, the evaporator temperature to be 271K (i.e. -2 ºC).
- Exergy destruction ratio (EDR) is decreasing while increasing evaporator temperature.
- Exergy destruction ratio(EDR) is also increases with increasing condenser temperature
- The best performances (COP and exergetic efficiency) were found using R290 hydrocarbon and R407c which is higher than R134a.
- Refrigerants R134a R404a and R507a give similar trends in their first law efficiency (COP), second law efficiency, exergetic efficiency and exergy destruction ratio, compressor efficiency, isentropic efficiency and volumetric efficiency with slightly variations.
- HFO-1234yf, R125 and R600a gives similar trends with slightly variation, however lower than R134a.
- Nano mixed R1234ze gives lowe performance as compared with nano mixed HFO-1234yf
- The worst performances were found by using R410a, R236fa
- Super worst first and second law performances were observed by using Al_2O_3 mixed in R245fa, R123 refrigerants.
- The Isentropic compressor efficiency and volumetric efficiency is also increases with increasing evaporator temperature and it has optimum value at 274K (i.e. 1ºC).
- first law efficiency (COP) decreases with decreasing condenser temperature
- Similarly isentropic efficiency and volumetric efficiency decreases by increasing condenser temperature.

References

[1] R. S. Mishra, Appropriate Vapour Compression Refrigeration Technologies for Sustainable Development International Journal of Advance Research & Innovations, 2014, 551-556

[2] D. Yumrutas et. al Exergy analysis of vapour compression refrigeration systems, Exergy, an Int J, 2 (2002) 266-272

[3] Dincer I. Refrigeration systems and applications. London: Wiley; 2003. pp. 26–27.

[4] Nikolaidis C, Probert D. Exergy-method analysis of a two stage vapor compression refrigeration plants performance. Appl Energy. 1998;60:241–56
[5] Bejan A, Theory of heat transfer irreversible refrigeration plants, Int J Heat mass transfer, 32(9), (1989), 1631-39.
[6] Sajadi A.R. [2011].Investigation of turbulent convective heat transfer and pressure drop of TiO2/water nano fluid in circular tube, International communications in Heat and mass transfer, Elsevier,Vol-38, page-1474-1478.
[7] Huang Dan , et.a. {2016] , Effect of hybrid nano fluid mixture in the plate heat exchangers, Experimental thermal and fluid science, Elsevier, Vol-72, pp 190-196.
[8] Zeinali S Heris et.al [2007] “Experimental investigation of convective heat transfer coefficient using Al_2O_3 /water nano fluid in circular tube” , J of Heat & fluid flow, Elsevier, Vol-28, page-203-210.