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Thermal performances (first law efficiency, exergy destruction ratio & exergetic efficiency) of cascade single effect ammonia-water (NH_3-H_20) vapour absorption refrigeration system coupled with vapour compression refrigeration using ecofriendly refrigerants in the low temperature cycle of VCRS system

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Abstract

Solar thermal power energy and waste heat from different power plants have immense application potential for production of refrigeration through combined vapour compression–absorption refrigeration systems. The aim of this work is to develop an integrated solar refrigeration system where waste heat from different energy resources assists a combined vapour absorption compression system, and to analyze feasibility & practicality of that system of thermodynamically for improving its COP and exergetic efficiency by reduction of irreversibilities in terms of exergy destruction /losses occurred in the system components. The combined thermodynamic first law efficiency in terms of coefficient of performance (COP_Overall), second law efficiency in terms of exergetic efficiency and exergy destruction ratio based on exergy of product of a combined vapour absorption-compression system working with each of the following refrigerants in the cascaded vapour compression cycle R1234yf, R227ea, R236fa, R245fa, R143a,R134a, R32, R507 operating at - 223 K evaporator temperature with temperature overlapping (Approach means the difference between cascaded condenser temperature of vapour compression cycle and evaporator temperature of vapour absorption refrigeration cycle working at 13.5 bar of highest generator pressure and 1.75 bar as lowest evaporator pressure have been presented and it is found thatR141b and R245fa gives better performance

Keywords: Low GWP Refrigerants, Energy-Exergy Analysis, Single effect VAR-Cascade VCR System,

1. Introduction

Vapor compression refrigeration system (VCRS) is widely used refrigeration system (about 80%) and requires a large amount of electrical energy for its operation. The advancement in refrigeration sector has a major impact on energy demand which approximates to 15% of the total energy consumption in the world. Many developing countries like India currently suffer from a major shortage of electricity. Around 55% of the total electrical capacity is generated using coal in India [1].

Solar thermal power energy and waste heat from different power plants have immense application potential for production of refrigeration through combined vapour compression absorption refrigeration systems. The aim of this work is to develop an integrated solar refrigeration system where waste heat from different energy resources assists a combined vapour absorption -compression system, and to analyze feasibility & practicality of that system of thermodynamically for improving its COP and exergetic efficiency by reduction of irreversibilities in terms of exergy destruction /losses occurred in the system components [2].

The combined refrigeration system consists of a conventional vapour compression refrigeration system cascaded with vapour absorption system. The LiBr–H_2O couples is used for the absorption refrigeration system and nine different refrigerants (i.e.R1234yf, R227ea, R236fa, R245fa , R141b,R134a, R32, R507, R717, are evaluated to find the best suitable ecofriendly) for cascaded vapour compression system and found that first law efficiency of combined cycle cascaded of evaporator of vapour absorption cycle with

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condenser of vapour compression cycle found 55.36% enhancement in overall COP of combined cycle using double effect vapour absorption LiBr-H2O system and 80% enhancement in overall COP of combined cycle using double effect vapour absorption LiBr-H_2O system as compared to single effect LIBr-H_2O) system for -323 K of evaporator VCR temperature using R134a while 16% improvement in COP using triple effect VARS as compared to double effect VARS cascaded with VCRS. Similarly Second law efficiency of combined cycle cascaded of evaporator of vapour absorption cycle with condenser of vapour compression cycle found 11.29% enhancement in overall COP of combined cycle using double effect vapour absorption LiBr-H_2O system and 21.8% enhancement in overall COP of combined cycle using double effect vapour absorption LiBr-H_2O system as compared to single feect LIBr-H_2O) system for -323 K of evaporator VCR temperature using R134a while 9.44% improvement in COP using triple effect VARS as compared to double effect VARS cascaded with VCRS [3]

The present paper provided the best refrigerant for the novel combined vapour absorption refrigeration cycle/cascaded with vapour compression cycle to provide the highest thermodynamic efficiency for lowest degree of environmental damage.

2. Literature Review

Jain et al. [1] studied various integrated refrigeration systems and concluded that these systems are promising energy efficient and decarbonizing cooling technology in near future. Riiffit S.B., Shankland N [4] thermo-dynamically analyzed different types of integrated single-effect, double-effect series and the double-effect parallel continuous absorption systems and their integration with vapour-compression systems using various refrigerant/absorbent pairs and intermittent absorption system, the intermittent absorption/vapour recompression system and the combined intermittent absorption/vapour compression system.L. Kairouani, E. Nehdi [5] carried out thermodynamic analysis of novel combined refrigeration system using geothermal energy temperature source in the range 343–349 K supplied to a generator operating at 335 K.to supply vapour absorption system cascaded with conventional compression system using three working fluids (i.e.R717, R22, and R134a) and found that the COP can be improved by 37–54%, as compared with the conventional cycle, under the same operating conditions, (i.e. Vaporization temperature of 263 K and a condensation temperature of 308 K). Results of this studied show that the COP of a combined system is significantly higher than that of a single stage refrigeration system. For industrial refrigeration, the proposed system constitutes an alternative solution for reducing energy consumption and greenhouse gas emissions

3. Results and Discussions

Table-1 shows the variation of thermal performance parameters of single effect cascade vapour absorption refrigeration system using lithium bromide -water solution coupled with vapour compression refrigeration system. The evaporator of VARS is cascaded with condenser of vapour compression refrigeration systems using nine ecofriendly refrigerants. It is found that overall first law efficiency in terms of coefficient of performance (COP) of cascade refrigeration system using R245fa refrigerant is highest and lowest by using R227ea as shown in fig-1 .while exergy destruction of cascade system is lowest by using R141b and highest while using R227ea as shown in Fig-2. The cascade system exergetic efficiency is highest by using R141b and lowest by using R227ea as shown in Fig-3. The thermal performances using ecofriendly refrigerants in the low temperature circuit of vapour compression refrigeration system is shown in Table-1 and it is found that maximum coefficient of performance (COP)of vapour compression refrigeration system by using R141b and lower COP by using R227ea respectively as shown in Fig-4. Similarly exergy destruction of vapour compression refrigeration system is lowest by using R141b and highest while using R227ea as shown in Fig-5. The exergetic efficiency of vapour compression of refrigeration system is highest by using R141b and lowest by using R227ea as shown in Fig-6

Table 1: Thermal performances of single effect (NH_3-H_20) vapour absorption refrigeration system using vapour compression refrigeration system (T_Eva_VARS= -20°C, approach_VCRS=10°C, T_Eva_Ref= -50°C, compressor efficiency=0.80, generator heat exchanger effectiveness= 0.6894

Refrigerant	COP (Overall)	Overall Exergy Destruction ratio (EDR)	Overall Exergetic Efficiency	COP (VCRS)	VCRS Exergy destruction Ratio (EDR)	VCRS Exergetic Efficiency
R134a	0.4554	1.998	0.3335	1.485	1.002	0.4995
R1234yf	0.4463	2.152	0.3173	1.356	1.192	0.4561
R141b	0.4699	1.773	0.3607	1.719	0.7301	0.5780
R227ea	0.4331	2.394	0.2947	1.188	1.503	0.3996
R236fa	0.4474	2.133	0.3192	1.371	1.169	0.4610
R245fa	0.4596	1.930	0.3413	1.55	0.9188	0.5212
R32	0.4558	1.992	0.3342	1.491	0.9947	0.5013
R507a	0.4426	2.217	0.3109	1.387	1.275	0.4396

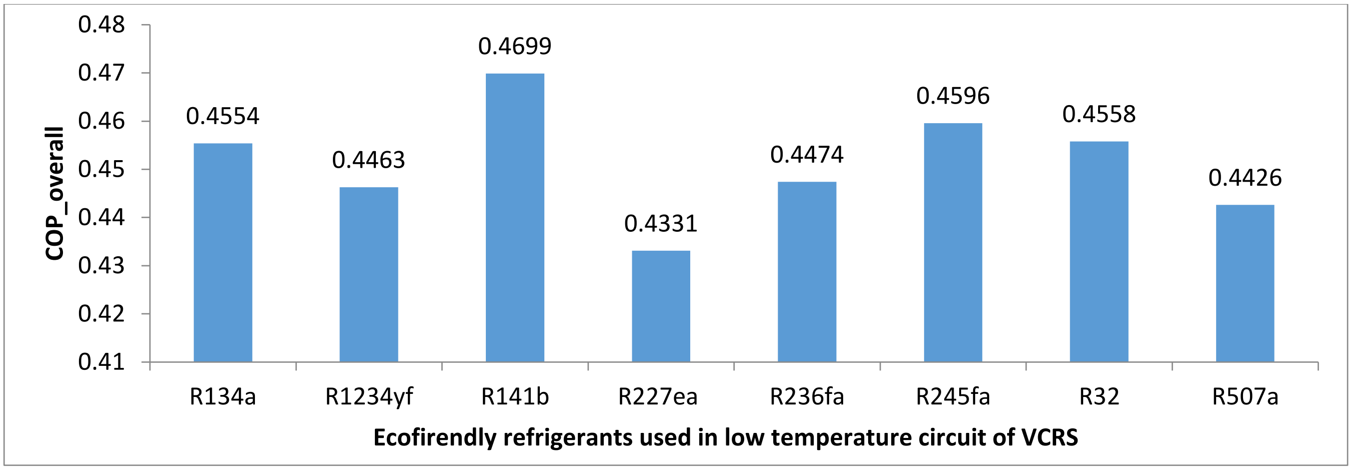

Figure 1: *Thermal performances in terms of first law efficiency (overall COP_Cascade) of cascade single effect ammonia-water(NH_3-H_20) vapour absorption refrigeration system coupled with vapour compression refrigeration using ecofriendly refrigerants in the low temperature cycle of VCRS system*

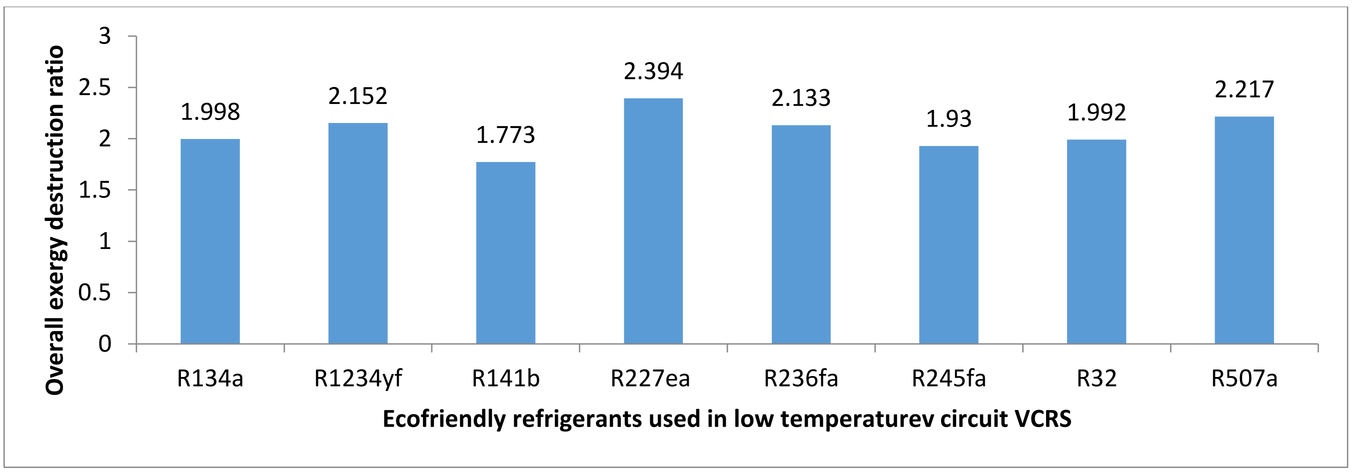

Figure 2: Thermal performances in terms of overall exergy destruction ratio (EDR_Overall) of cascade single effect ammonia-water (NH_3-H_20) with vapour absorption refrigeration system coupled with vapour compression refrigeration using ecofriendly refrigerants in the low temperature cycle of VCRS system

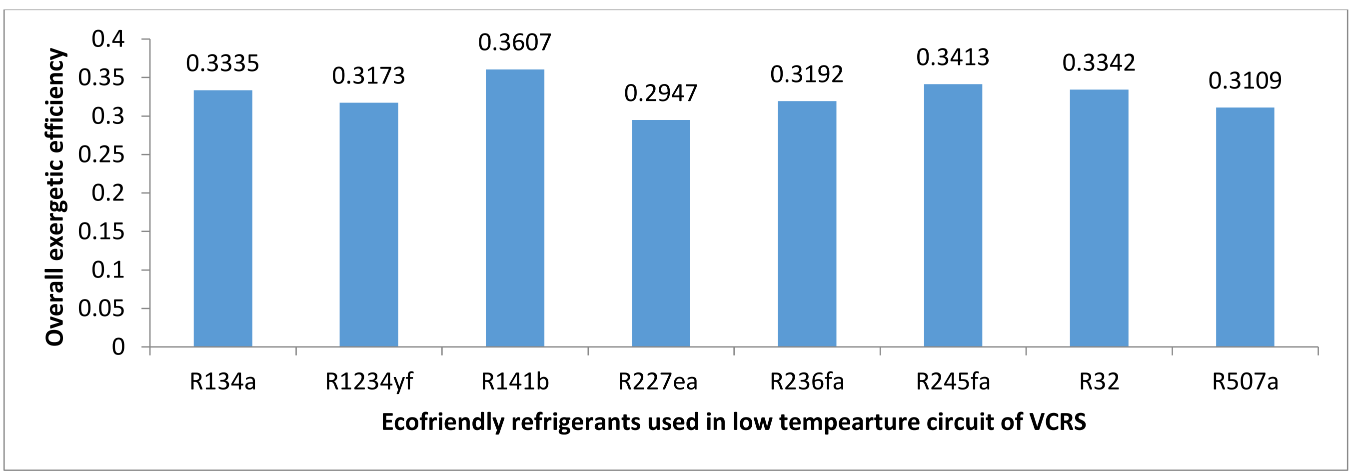

Figure 3: *Thermal performances in terms of overall exergetic efficiency of cascaded single effect ammonia-water (NH_3-H_20) with vapour absorption refrigeration system coupled with vapour compression refrigeration using ecofriendly refrigerants in the low temperature cycle of VCRS system*

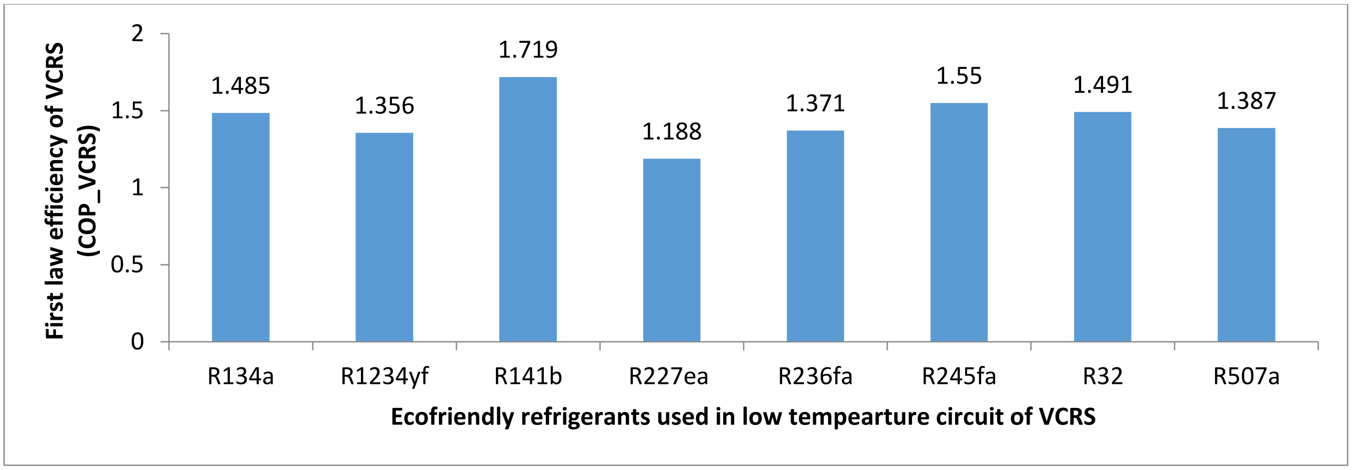

Figure 4: *Thermal performances in terms of first law efficiency of vapour compression refrigeration system (COP_VCRS) of cascaded with single effect ammonia-water (NH_3-H_20) vapour absorption refrigeration system coupled with vapour compression refrigeration using ecofriendly refrigerants in the low temperature cycle of VCRS system*

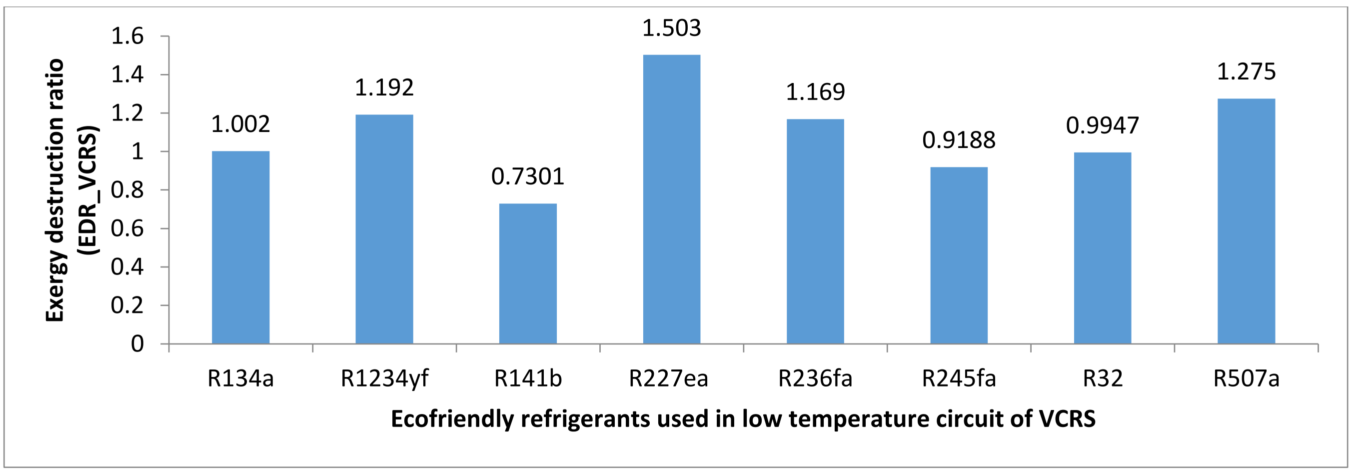

Figure 5: Thermal performances in terms of exergy destruction ratio (EDR_VCRS) of vapour compression system of vapour compression refrigeration system (COP_VCRS), of cascaded with single effect ammonia-water (NH_3-H_20) vapour absorption refrigeration system coupled with vapour compression refrigeration using ecofriendly refrigerants in the low temperature cycle of VCRS system

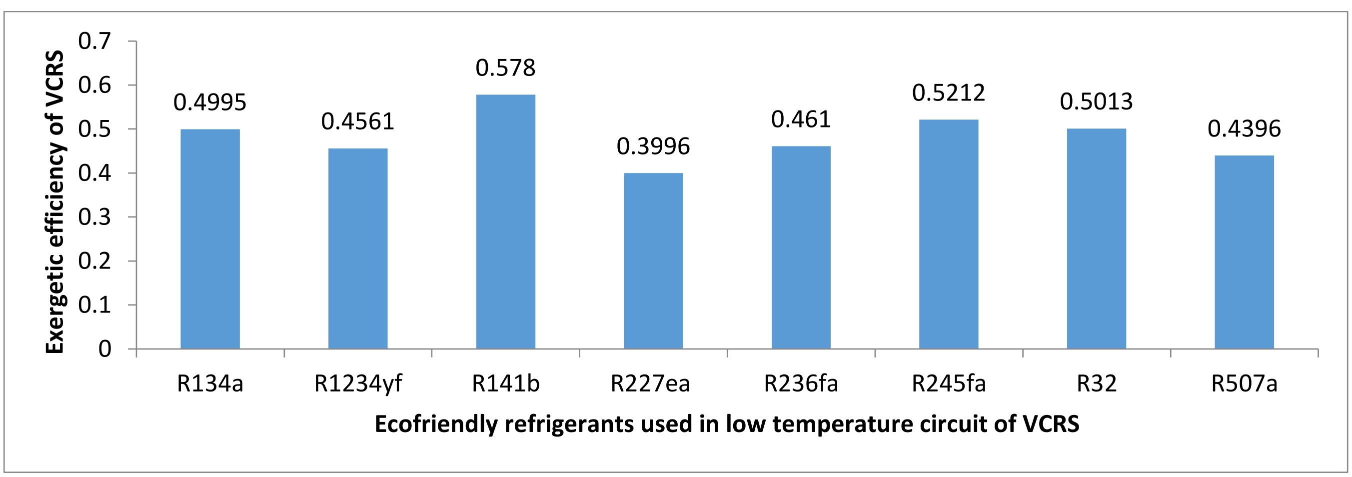

Figure 6: Thermal performances in terms of exergetic efficiency of vapour compression system of vapour compression refrigeration system (COP_VCRS), of cascaded with single effect ammonia-water(NH_3-H_20) vapour absorption refrigeration system coupled with vapour compression refrigeration using ecofriendly refrigerants in the low temperature cycle of VCRS system

The percentage improvement in thermal performance of combined novel vapour absorption refrigeration system coupled with vapour compression refrigeration system is shown in Table-2. It is found that this system combined single effect NH_3-H_2O vapour absorption system combined with vapour compression system using R141b ecofriendly refrigerant gives best first law performance(COP_Overall) improvement around 45.65% along with 45.73% improvement second law performance in terms of exergetic efficiency. However minimum exergy destruction ratio by using R227ea

Table-2: Percentage improvements in thermal performances of single effect NH_3_H_2O vapour absorption system cascaded with vapour compression refrigeration system using ecofriendly refrigerants

Performance Parameters	% First law Performance improvement (COP)	% II law Performance improvement (Exergetic)	% Reduction in Irreversibility (EDR)
R134a	41.428	34.34	34.29
R1234yf	38.60	28.20	29.0
R227ea	34.50	19.07	21.30
R236fa	38.912	28.96	29.88
R245fa	42.7	37.89	36.55
R32	41.55	35.03	34.51
R141b	45.65	45.73	41.71
R507a	37.45	25.61	27.12

4. Conclusions

The following conclusions were drawn.

(i) The thermodynamic performance in terms of first law efficiency and second law efficiency improved significantly by using vapour absorption system cascaded with vapour compression refrigeration system.

(ii) The 45.65% improvement in first law efficiency (i.e. over all COP) of combined single effect vapour absorption refrigeration cascade system using R141b refrigerant in the vapour compression cycle is found as compared to single effect NH_3H_2O vapour absorption refrigeration system

(iii) 45.73% increment of second law efficiency (i.e. exergetic efficiency) of the single effect NH_3H_2O vapour absorption refrigeration system cascaded with vapour compression refrigeration system is found as compared to single effect NH_3H_2O vapour absorption-refrigeration system

(iv) Minimum exergy destruction ratio in the single effect NH_3H_2O vapour absorption refrigeration system cascaded with vapour compression refrigeration system by using R227ea is found as compared to single effect NH_3H_2O vapour absorption- refrigeration system.

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