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Methods for improving thermodynamic performances of vapour absorption refrigeration system cascaded with vapour compression refrigeration systems using ecofriendly refrigerants

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Abstract

In this paper, the performance improvement of vapour absorption refrigeration system by cascading vapour compression refrigeration system using various ecofriendly refrigerants for low temperature evaporator temperature of -53^{0}C have been presented. The effect of ecofriendly alternate refrigerants on NH_3H_2O cascaded vapour compression -absorption system and half effect, cascaded VARS-VCRS system, single effect , double effect and triple effect Li/Br-H_2O vapour absorption refrigeration system cascaded by vapour compression refrigeration system and it was found that the thermal performances of cascaded refrigeration using ecofriendly R141b refrigerants gives best thermodynamic performances in terms of first law efficiency and second law efficiency (exergetic efficiency) and percentage increment in terms of exergetic efficiency .The performance using Li/Br vapour absorption refrigeration system cascaded with vapour compression refrigeration system is high as compared to NH_3H_2O vapour absorption refrigeration system cascaded with vapour compression refrigeration system but using cascaded vapour compression system with NH_3H_2O , the improvement in thermal performances at -53^{0}C of evaporator temperature of VCRS is maximum (47.7138%) and minimum (11.23%) was observed using triple effect Li/Br cascaded absorption -compression refrigeration systems. The thermodynamic performance of HFO-1234yf in cascaded vapour absorption -compression system is slightly less as compared to R134a. However the performance of R717, Hydrocarbons (R290 and R600a) is slightly matching with the performance using R134a .The Performance of R123 and R141b is also slightly matching with 3% to 5% difference.

Keywords: Thermodynamic performances, cascaded vapour compression-absorption refrigeration systems.

1. Introduction

Vapor compression refrigeration system is normally used refrigeration system (around 80%) and requires a large amount of electrical energy for its operation. The advancement in refrigeration area 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 56% of the total electrical capacity is generated using coal in India. The depletion of fossil fuel, also results in the production of harmful gases due to the burning of fossil fuel, which causes greenhouse effect and declines the environment. But, energy conservation and ecological safety are the vital requirement for the sustainable development of any country. One of the alternatives to reduce the dependence on electrically powered VCRS with vapour absorption refrigeration system. The vapour absorption refrigeration system operate on heat energy input. Several investigators have studied the performance of vapour absorption refrigeration system o considering H_2O-LiBr as a working pair. This system is generally used for the air conditioning purposes as it can maintain the evaporator temperature up to 5°C. For low temperature applications i.e. below 5°C, working pair of NH_3-H_2O is used in VARS [6]. Although NH_3-H_2O does not form an ideal pair for the absorption system because it produces ammonia mixed with water vapour at the exit of the generator. Water in the refrigerant stream can cause operational problems in the

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evaporator of the system. Thus H_2O-LiBr fluid pair is suitable from the view point of solubility and boiling point requirements [1]. Cimsit and Ozturk [2] theoretically analyzed thermal performance of vapour compression absorption cascaded refrigeration system (VCACRS) with H_2O-LiBr and NH_3-H_2O as fluid pair in absorption section and R134a, R410A and NH3 refrigerants in the compression section of cascaded refrigeration system and found 48-51% less electrical energy consumption than conventional vapour compression refrigeration system. Chinnappa et al. [3] described a vapour compression absorption cascaded refrigeration system consisting of a conventional R22 VCRS cascaded with a solar operated, NH_3-H_2O, VARS for air conditioning application. It was found to yield 49.5% saving in electrical energy consumption by the compression system.

Nehdi [4] carried out theoretically the comparative performance of three refrigerants (R717, R22, R134a) in the compression section with NH_3-H_2O fluid pair in the absorption section of the vapour compression–absorption cascaded refrigeration system using eothermal heat supplied in the generator at the temperature of 335 K for a fixed evaporation temperature of 263 K. The highest performance was obtained by R717and found refrigeration effect of about 10 MW with the compressor power of 1.65 MW and concluded that the same refrigeration effect could be produced by a conventional VCRS by consuming 3.6 MW of electricity which was 54% more than the combined installation consumption. The investigators have not computed the percentage improvementin the first and second law efficiency and also % reduction in the exergy destruction ratio based on exergy of product. by using cascadevapour-absorption-compresion refrigeration system using alternative refrigerants. The present investigation mainly deals with the performnce enhencement using cascaded vapour absorption-compression systems of four Li/Br- H_2O systems using half effect, single effect, double effect and tripple effect along with NH_3H_2O absorption cascaded vapour compression system.

2. Results and Discussions

Five vapour absorption refrigeration system cascaded with vapour compression refrigeration system have been considered and following input data have been used for various systems are given below.

System-1: LI/Br Tripple effect vapour absorption refrigeration system cascaded with vapour compression refrigeration system using following ecofriendly refrigerants.

(i) Temperature of Absorber=35^0C.
(ii) Temperature of Condenser=35^0C
(iii) Temperature of Generator=180^0C
(iv) Evaporator temperature of vapour compression refrigeration system= 5^0C (for system-1(a) and 8^0C for system-1(b)
(v) Evaporator temperature of vapour compression refrigeration system= -53^0C
(vi) Compressor efficiency=0.8
(vii) Heat exchanger effectiveness =0.5
(viii) Refrigeration effect =29.09"kW"
(ix) Temperature overlapping=10^0C

System 2(a): LI/Br Double effect vapour absorption refrigeration system cascaded with vapour compression refrigeration system using following ecofriendly refrigerants.

(i) Temperature of Absorber=35^0C.
(ii) Temperature of Condenser=35^0C
(iii) Temperature of Generator=80^0C
(iv) Evaporator temperature of vapour compression refrigeration system= 5^0C
(v) Evaporator temperature of vapour compression refrigeration system= -53^0C
(vi) Compressor efficiency=0.8
(vii) Heat exchanger effectiveness =0.5
(viii) Refrigeration effect =29.09"kW
(ix) Temperature overlapping=10^0C

System-2(b): Li/Br Double effect vapour absorption refrigeration refrigeration system cascaded with vapour compression refrigeration system using following ecofriendly refrigerants.

(i) Temperature of Absorber=35^0C.
(ii) Temperature of Condenser=35^0C
(iii) Temperature of Generator=80^0C
(iv) Evaporator temperature of vapour compression refrigeration system= 5^0C
(v) Evaporator temperature of vapour compression refrigeration system= -53^0 C
(vi) Compressor efficiency=0.8
(vii) Heat exchanger effectiveness =0.5
(viii) Refrigeration effect =29.09"kW
(ix) Temperature overlapping=10 ^{o}C

System2-(c): LI/Br Double effect vapour absorption refrigeration system cascaded with vapour compression refrigeration system using following ecofriendly refrigerants.

(i) Temperature of Absorber=35^{o}C.
(ii) Temperature of Condenser=35^{o}C
(iii) Temperature of Generator=80^{o}C
(iv) Evaporator temperature of vapour compression refrigeration system= 5 ^{o}C
(v) Evaporator temperature of vapour compression refrigeration system= -53 ^{o}C
(vi) Compressor efficiency=0.8
(vii) Heat exchanger effectiveness =0.5
(viii) Refrigeration effect =29.09"kW

System3: Li/Br Single effect vapour absorption refrigeration system cascaded with vapour compression refrigeration system using following ecofriendly refrigerants.

(i) Temperature of Absorber=35^0C.
(ii) Temperature of Condenser=35^0C
(iii) Temperature of Generator=110^0C
(iv) Evaporator temperature of vapour compression refrigeration system= 5^0C
(v) Evaporator temperature of vapour compression

refrigeration system= -53^{0}C
(vi) Compressor efficiency=0.8
(vii) Heat exchanger effectiveness =0.5
(viii) Refrigeration effect =29.09"kW"
(ix) Temperature overlapping=10^{0}C

System4: Li/Br Half effect vapour absorption refrigeration system cascaded with vapour compression refrigeration system using following ecofriendly refrigerants.
(i) Temperature of Absorber=35^{0}C.
(ii) Temperature of Condenser=35^{0}C
(iii) Temperature of Generator=80^{0}C
(iv) Evaporator temperature of vapour compression refrigeration system= 5^{0}C
(v) Evaporator temperature of vapour compression refrigeration system= -53^{0}C
(vi) Compressor efficiency=0.8
(vii) Heat exchanger effectiveness =0.5
(viii) Refrigeration effect =29.09"kW"
(ix) Temperature overlapping=10^{0}C

System 5: NH_3H_20 Vapour absorption refrigeration system cascaded with vapour compression refrigeration system using following ecofriendly refrigerants.
(i) Temperature of Absorber=35^{0}C.
(ii) Temperature of Condenser=35^{0}C
(iii) Temperature of Generator=80^{0}C
(iv) Evaporator temperature of vapour compression refrigeration system= 5^{0}C
(v) Evaporator temperature of vapour compression refrigeration system= -53^{0}C
(vi) Compressor efficiency=0.8
(vii) Heat exchanger effectiveness =0.5
(viii) Refrigeration effect =29.09"kW"
Temperature overlapping=10^{0}C

Table-1(a) shows the effect of ecofriendly alternate refrigerants on performance improvement in the triple effect Li/Br vapour absorption refrigeration system at 8^{o}C of evaporator temperature cascaded by vapour compression refrigeration system and it was found that the thermal performances of cascaded refrigeration using ecofriendly R-141b refrigerants gives best thermodynamic performances in terms of first law efficiency (COP) and second law efficiency in terms of exergetic efficiency. The thermodynamic performance of HFO refrigerant is slightly lesser than using HFC-134a in the cascaded vapour absorption-compression refrigeration system.Table-1(b) shows the performance improvement in vapour compression-absorption cascaded systems at evaporator temperature of vapour absorption system is 5^{o}C with temperature overlapping of 10^{o}C in cascade condenser and found that by using ecofriendly R-141b refrigerants gives best thermodynamic performances in terms of first law efficiency (COP) and second law efficiency in terms of exergetic efficiency. Table-2(a)to Table-2(c) show the effect of approach in terms of temperature overlapping between cascade evaporator and cascade condenser and it was found that performance improved at 5oC temperature overlapping and maximum first and second law efficiency is observed by using R141b refrigerant and lowest by using R744 refrigerant. It is also found that first and second law efficiencies of double effect vapour absorption cascaded with vapour compression system is lower than triple effect vapour absorption cascaded with vapour compression refrigeration system and higher than single effect and half effect Li/Br absorption system cascaded with vapour compression refrigeration system using ecofriendly refrigerants. The first and second law performance improvement in double effect is more than triple effect vapour absorption-cascaded vapour compression refrigeration systems. The performance of single effect Li/Br vapour absorption system cascaded with vapour compression system and half effect Li/Br refrigeration system cascaded with vapour compression refrigeration systems using ecofriendly refrigerants are presented in Table-3 & Table-4 respectively.it was observed that first and second law performances of single effect vapour absorption refrigeration system is higher than half effect Li/Br-H_2O vapour absorption cascaded with vapour compression refrigeration system , but performance enhancement in the first law efficiency (COP) and exergetic efficiency using half effect is more than single effect vapour absorption cascaded vapour compression refrigeration system as shown in table-4.

Table1(a):Variation Thermal performances of Triple effect LiBr-H_2O vapour absorption refrigeration cascaded with vapour compression refrigeration system using ecofriendly refrigerants (COP_VARS=1.478, EDR_VARS=2.824, Exergetic Efficiency_VARS=0.2613,T_EVA=8^{o}C, Absorber temperature=35^{o}C, generator temperature=180^{o}C, Condenser temperature_VARS=35^{o}C, Collector Area= 31.65 m^2), Compressor efficiency=0.80, T_EVA=-53^{o}C, Approach (temperature overlapping) =10,

Ecofriendly Refrigerants	COP	% Increment	EDR	% decrement	Exergetic Efficiency	% increment
R134a	1.585	7.239513	1.052	62.74788	0.4873	86.49062
R1234yf	1.551	4.939107	1.137	59.73796	0.4679	79.06621
R152a	1.612	9.066306	0.9884	65	0.5029	92.46077
R290	1.583	7.104195	1.056	62.60623	0.4861	86.03138
R600a	1.592	7.713126	1.034	63.38527	0.4916	88.13624
R600	1.605	8.592693	1.003	64.483	0.4982	90.66207
R245fa	1.601	8.322057	1.012	64.16431	0.4971	90.2411
R236fa	1.554	5.142084	1.121	60.30453	0.470	79.86988
R227ea	1.491	0.879567	1.296	54.10765	0.4356	66.70494
R141b	1.647	11.43437	0.9085	67.82932	0.521	99.38768

R143a	1.546	4.600812	1.147	59.38385	0.466	78.33907
R717	1.584	7.171854	1.054	62.67705	0.4860	85.99311
R32	1.577	6.698241	1.07	62.11048	0.4832	84.92155
R507a	1.529	3.450609	1.193	57.75496	0.4560	74.51206
R125	1.495	1.150203	1.285	54.49717	0.430	64.56181
R123	1.621	9.675237	0.967	65.75779	0.5084	94.56563
R410a	1.568	6.08931	1.092	61.33144	0.4779	82.89323
R404a	1.525	3.179973	1.204	57.36544	0.456	74.51206
R407c	1.51	2.165088	1.244	55.94901	0.446	70.68504
R-744	1.4781	0.00677	1.486	47.3796	0.4023	53.96096

Table1 (b): Variation Thermal performances of Tripple effect LiBr-H_2O vapour absorption refrigeration cascaded with vapour compression refrigeration system using ecofriendly refrigerants (COP_VARS=1.21, EDR_VARS=3.240, Exergetic Efficiency_VARS=0.2358 for T_EVA=5°C, Absorber temperature=35°C, generator temperature=180°C, Condenser temperature_VARS=35°C, Collector Area= 31.65 m^2), Compressor efficiency=0.80, T_EVA= - 53°C, Approach (temperature overlapping) =10,

Ecofriendly Refrigerants	COP	% increment	EDR	% decrement	Exergetic efficiency	% increment
R134a	1.339	19.44692	1.134	65	0.4686	98.72774
R1234yf	1.317	17.48439	1.205	62.80864	0.4536	92.36641
R152a	1.357	21.05263	1.080	66.66667	0.4807	103.8592
R290	1.338	19.35772	1.137	64.90741	0.4680	98.47328
R600a	1.336	19.1793	1.144	64.69136	0.4664	97.79474
R600	1.354	20.78501	1.081	66.6358	0.4763	101.9932
R245fa	1.351	20.5174	1.098	66.11111	0.4765	102.078
R236fa	1.318	17.5736	1.201	62.9321	0.4543	92.66327
R227ea	1.28	14.18376	1.328	59.01235	0.4295	82.14589
R141b	1.382	23.28278	1.008	68.88889	0.4979	111.1535
R143a	1.314	17.21677	1.214	62.53086	0.4517	91.56064
R717	1.336	19.1793	1.145	64.66049	0.4661	97.66751
R32	1.333	18.91169	1.154	64.38272	0.4643	96.90416
R507a	1.306	16.50312	1.239	61.75926	0.4466	89.39779
R125	1.28	14.18376	1.328	59.01235	0.4296	82.1883
R123	1.364	21.67707	1.060	67.28395	0.4854	105.8524
R410a	1.336	19.1793	1.145	64.66049	0.4662	97.70992
R404a	1.297	15.70027	1.27	60.80247	0.4405	86.81086
R407c	1.276	13.82694	1.34	58.64198	0.4274	81.2553
R-744	1.233	9.991079	1.498	53.76543	0.4002	69.7201

Table-2(a):Variation Thermal performances of Double effect LiBr-H_2O vapour absorption refrigeration cascaded with vapour compression refrigeration system using ecofriendly refrigerants (COP_VARS=1.112, EDR_VARS=2.491, Exergetic Efficiency_VARS=0.2864,T_EVA=5°C, Absorber temperature=35°C, generator temperature=130°C, Condenser temperature_$_{VARS}$=35°C, Collector Area= 31.65 m^2), Compressor efficiency=0.80, T_EVA=-53°C, Approach (temperature overlapping) =10,

Ecofriendly Refrigerants	COP	% Increment	EDR_ Cascade	% decrement	Exergetic efficiency	% increment
R134a	1.331	19.69424	0.9798	60.78683	0.5051	76.36173
R1234yf	1.309	17.71583	1.048	58.04898	0.4883	70.49581
R152a	1.349	21.31295	0.9277	62.87836	0.5188	81.14525
R290	1.331	19.69424	0.9816	60.71457	0.5046	76.18715
R600a	1.337	20.23381	0.9629	61.46527	0.5096	77.93296
R600	1.346	21.04317	0.9376	62.48093	0.5161	80.20251
R245fa	1.343	20.77338	0.9452	62.17583	0.5141	79.50419
R236fa	1.311	17.89568	1.041	58.32999	0.4899	71.05447
R227ea	1.269	14.11871	1.178	52.83019	0.4591	60.30028
R141b	1.374	23.56115	0.8578	65.68446	0.5383	87.95391
R143a	1.306	17.44604	1.057	57.68768	0.4861	69.72765
R717	1.328	19.42446	0.9904	60.3613	0.5024	75.41899

M32	1.325	19.15468	0.9992	60.00803	0.5002	74.65084
R507a	1.294	16.36691	1.094	56.20233	0.4775	66.72486
R125	1.272	14.38849	1.168	53.23163	0.4612	61.03352
R123	1.356	21.94245	0.9078	63.67724	0.5242	83.03073
R404a	1.291	16.09712	1.106	55.72059	0.4749	65.81704
R-407c	1.275	14.65827	1.160	53.55279	0.4630	61.66201
R744	1.226	10.2518	1.333	46.60779	0.4287	49.68575

Table-2(b): Variation Thermal performances of Double effect LiBr-H_2O vapour absorption refrigeration cascaded with vapour compression refrigeration system using ecofriendly refrigerants (COP_{VARS}=1.201, EDR_{VARS}=2.802, Exergetic $Efficiency_{VARS}$=0.261, For T_EVA=8°C, Absorber temperature=35°C, generator temperature=130°C, Condenser temperature_VARS=35°C, Collector Area= 31.65 m^2), Compressor efficiency=0.80, T_EVA=-53°C, Approach (temperature overlapping) =10,

Ecofriendly Refrigerants	COP	% increment	$EDR_{Cascade}$	% decrement	Exergetic efficiency	% increment
R134a	1.377	14.65445	1.079	61.49179	0.4811	84.3295
R1234yf	1.350	12.40633	1.164	58.45824	0.4621	77.04981
R152a	1.399	16.48626	1.015	63.77587	0.4964	90.19157
R290	1.376	14.57119	1.082	61.38473	0.4803	84.02299
R600a	1.373	14.3214	1.091	61.06353	0.4782	83.21839
R600	1.394	16.06994	1.029	63.27623	0.4929	88.85057
R245fa	1.391	15.82015	1.037	62.99072	0.4908	88.04598
R236fa	1.351	12.48959	1.159	58.63669	0.4632	77.47126
R227ea	1.306	8.742714	1.310	53.24768	0.4328	65.82375
R141b	1.427	18.81765	0.9336	66.68094	0.5172	98.16092
R143a	1.347	12.15654	1.174	58.10136	0.4601	76.28352
R717	1.377	14.65445	1.08	61.4561	0.4808	84.21456
M32	1.372	14.23813	1.095	60.92077	0.4773	82.87356
R507a	1.337	11.3239	1.204	57.03069	0.4535	73.75479
R125	1.306	8.742714	1.311	53.21199	0.4327	65.78544
R123	1.406	17.06911	0.9929	64.5646	0.5018	92.26054
R404a	1.327	10.49126	1.238	55.81727	0.4469	71.22605
R-407c	1.311	9.159034	1.293	53.85439	0.4360	67.04981
R744	1.252	4.246461	1.514	45.96717	0.3978	52.41379

Table-2(c):Variation Thermal performances of Double effect LiBr-H_2O vapour absorption refrigeration cascaded with vapour compression refrigeration system using ecofriendly refrigerants (COP_VARS=1.201, EDR_VARS=2.802, Exergetic Efficiency_VARS=0.263,T_EVA=8°C, Absorber temperature=35°C, Condenser temperature_VARS=35°C, Collector Area= 31.65 m^2), Compressor efficiency=0.80, T_EVA=-50°C, Approach (temperature overlapping) =5

Ecofriendly Refrigerants	COP	% increment	EDR	% decrement	Exergetic Efficiency	% increment
R134a	1.411	17.48543	1.065	61.99143	0.4843	85.55556
R1234yf	1.381	14.98751	1.155	58.77944	0.4640	77.77778
R152a	1.432	19.23397	1.005	64.13276	0.4988	91.11111
R290	1.409	17.3189	1.068	61.88437	0.4835	85.24904
R600a	1.417	17.98501	1.047	62.63383	0.4886	87.20307
R600	1.427	18.81765	1.018	63.66881	0.4956	89.88506
R245fa	1.425	18.65112	1.025	63.41899	0.4939	89.23372
R236fa	1.388	15.57036	1.132	59.60029	0.4690	79.69349
R227ea	1.341	11.65695	1.286	54.10421	0.4375	67.62452
R141b	1.459	21.4821	0.9287	66.85582	0.5185	98.659
R143a	1.381	14.98751	1.155	58.77944	0.4641	77.81609
R717	1.411	17.48543	1.063	62.06281	0.4847	85.70881
M32	1.405	16.98585	1.082	61.38473	0.4803	84.02299
R507a	1.368	13.90508	1.197	57.28051	0.4552	74.40613
R125	1.342	11.74022	1.282	54.24697	0.4382	67.89272
R123	1.439	19.81682	0.9832	64.91078	0.5042	93.18008

R404a	1.364	13.57202	1.208	56.88794	0.4530	73.56322
R-407c	1.349	12.32306	1.256	55.17488	0.4433	69.84674
R744	1.285	6.994172	1.486	46.96645	0.4022	54.09962

Table-3:Variation Thermal performances of Single effect LiBr-H_2O vapour absorption refrigeration cascaded with vapour compression refrigeration system using ecofriendly refrigerants (COP_VARS=0.7410, EDR_VARS=3.462 , Exergetic Efficiency_VARS=0.2101, T_EVA=5°C, Absorber temperature=35°C, generator temperature=110°C, Condenser temperature_VARS=35°C, Collector Area= 51.31 m^2), Compressor efficiency=0.80, T_EVA=-53°C, Approach (temperature overlapping) =10

Ecofriendly Refrigerants	COP	% increment	$EDR_{Cascade}$	% decrement	Exergetic efficiency	% increment
R134a	0.9970	34.54791	1.105	68.08203	0.4751	126.1304
R1234yf	0.9839	32.78003	1.169	66.23339	0.4610	119.4193
R152a	1.007	35.89744	1.055	69.52629	0.4866	131.604
R290	0.9963	34.45344	1.108	67.99538	0.4743	125.7496
R600a	0.9951	34.2915	1.114	67.82207	0.4731	125.1785
R600	1.105	49.12281	1.064	69.26632	0.4844	130.5569
R245fa	1.004	35.49258	1.071	69.06412	0.4829	129.8429
R236fa	0.9846	32.87449	1.166	66.32005	0.4618	119.8001
R227ea	0.9624	29.87854	1.280	63.02715	0.4386	108.7577
R141b	1.022	37.92173	0.9882	71.45581	0.5030	139.4098
R143a	0.9817	32.48313	1.180	65.91566	0.4587	118.3246
R717	0.9953	34.31849	1.113	67.85095	0.4732	125.2261
M32	0.9929	33.9946	1.125	67.50433	0.4706	123.9886
R507a	0.9772	31.87584	1.203	65.2513	0.4539	116.04
R125	0.9617	29.78408	1.284	62.91161	0.4378	108.377
R123	1.102	48.71795	1.036	70.0751	0.4913	133.841
R410a	0.9946	34.22402	1.116	67.7643	0.4725	124.8929
R404a	0.9714	31.09312	1.233	64.38475	0.4478	113.1366
R-407c	0.9575	29.21727	1.307	62.24726	0.4335	106.3303
R744	0.9311	25.65452	1.456	57.94339	0.4072	93.81247

Table-4:Variation Thermal performances of half Effect LiBr-H_2O vapour absorption refrigeration cascaded with vapour compression refrigeration system using ecofriendly refrigerants (COP_VARS=0.4221 EDR_VARS=4.50, Exergetic $_{Efficiency\_VARS}$=0.1818,$T_{\_EVA}$=5°C, Absorber temperature=35°C, generator temperature=80°C, Condenser temperature_VARS=35°C, Collector Area= 90.09 m^2), Compressor efficiency=0.80, T_EVA=-53°C, Approach (temperature overlapping) =10,

Ecofriendly Refrigerants	COP	% increment	$EDR_{Cascade}$	% decrement	Exergetic Efficiency	% increment
R134a	0.6101	44.53921	2.463	45.26667	0.2887	58.80088
R1234yf	0.6019	42.59654	2.662	40.84444	0.2731	50.22002
R152a	0.6157	45.86591	2.335	48.11111	0.2999	64.9615
R290	0.6099	44.49183	2.468	45.15556	0.2884	58.63586
R600a	0.6119	44.96565	2.421	46.2	0.2923	60.78108
R600	0.6146	45.60531	2.359	47.57778	0.2977	63.75138
R245fa	0.6138	45.41578	2.378	47.15556	0.2960	62.81628
R236fa	0.6036	42.99929	2.618	41.82222	0.2764	52.0352
R227ea	0.5901	39.801	2.975	33.88889	0.2516	38.39384
R141b	0.6235	47.71381	2.167	51.84444	0.3157	73.65237
R143a	0.6020	42.62023	2.658	40.93333	0.2734	50.38504
R717	0.6089	44.25492	2.490	44.66667	0.2866	57.64576
M32	0.6080	44.0417	2.511	44.2	0.2848	56.65567
R507a	0.5983	41.74366	2.754	38.8	0.2664	46.53465
R125	0.5911	40.03791	2.948	34.48889	0.2533	39.32893
R123	0.6179	46.38711	2.287	49.17778	0.3042	67.32673
R404a	0.5972	41.48306	2.783	38.15556	0.2643	45.37954
R-407c	0.5919	40.22743	2.926	34.97778	0.2547	40.09901
R744	0.5759	36.43686	3.401	24.42222	0.2272	24.9725

Table-5: Variation Thermal performances of NH_3H_2O vapour absorption refrigeration cascaded with vapour compression refrigeration system using ecofriendly refrigerants (COP_VARS=0.322, EDR_VARS=6.594 , Exergetic Efficiency_VARS=0.1317,T_EVA=5°C, Absorber temperature=35°C, generator temperature=180°C, Condenser temperature_VARS=35°C, Collector Area= 31.65 m^2), Compressor efficiency=0.80, T_EVA=-53°C, Approach (temperature overlapping) =10,

Ecofriendly Refrigerants	$COP_{Cascade}$	% increment	$EDR_{Cascade}$	% decrement	$Exergetic\ Efficiency_{cascade}$	% increment
R134a	0.4903	52.26708	1.483	77.51	0.4026	205.6948
R1234yf	0.4863	51.02484	1.525	76.87	0.3961	200.7593
R152a	0.4936	53.29193	1.449	78.03	0.4083	210.0228
R290	0.4902	52.23602	1.484	77.49	0.4026	205.6948
R600a	0.4898	52.1118	1.488	77.43	0.4019	205.1632
R600	0.4931	53.13665	1.454	77.95	0.4075	209.4153
R245fa	0.4926	52.98137	1.46	77.86	0.4066	208.732
R236fa	0.4864	51.0559	1.524	76.89	0.3963	200.9112
R227ea	0.4791	48.78882	1.602	75.71	0.3843	191.7995
R141b	0.4985	54.81366	1.40	78.77	0.4167	216.4009
R143a	0.4856	50.80745	1.532	76.77	0.3949	199.8481
R717	0.4885	51.70807	1.502	77.22	0.3997	203.4928
M32	0.4885	51.70807	1.502	77.22	0.3997	203.4928
R507a	0.4840	50.31056	1.548	76.52	0.3924	197.9499
R125	0.4791	48.78882	1.601	75.72	0.3844	191.8755
R123	0.4950	53.72671	1.435	78.24	0.4107	211.8451
R404a	0.4820	49.68944	1.571	76.18	0.3890	195.3683
R-407c	0.4754	47.63975	1.642	75.10	0.3785	187.3956
R744	0.4694	45.7764	1.71	74.07	0.3689	180.1063

Table-5 shows the first and second law performance improvement in NH_3H_2O vapour absorption system cascaded with vapour compression refrigeration system using ecofriendly refrigerants and found that the thermodynamic (First and second law efficiencies) performances are lowest than Li/Br-H_2O system but the performance improvement is highest using cascaded vapour absorption system at -53°C temperature of evaporator of VCRS.

3. Conclusion

The following conclusions were drawn from present investigations.

(i) Maximum first law performance in terms of coefficient of performance have been found using triple effect vapour absorption-Compression refrigeration system as compared to double effect and single and half effect Li/Br vapour absorption-cascaded compression system 11.43437% using R141b refrigerant

(ii) The maximum first law performance in terms of coefficient of performance enhanced up to 54.81367% using R141b and minimum 45.77% using R744 in the NH_3H_2O vapour absorption refrigeration system

(iii) The first law efficiency (COP) enhancement in the half effect Li/Br vapour absorption refrigeration system cascaded with vapour compression refrigeration system using R141b is 47.714% and minimum 36.437% using R744 refrigerant.

(iv) For single effect Li/Br vapour absorption system cascaded with vapour compression refrigeration system 37.92% using R141b and 25.65% using R744.

(v) For double effect vapour absorption system, the enhancement in first law efficiency (COP) is 23.56% using R141b and 10.252% using R744 refrigerant

(vi) The first law enhancement of 23.283% using R141b and around 10% refrigerant in triple effect vapour absorption refrigeration system cascaded with vapour compression refrigeration system using R744.

(vii) The significantly enhancement in the second law efficiency (exergetic efficiency) was observed when vapour absorption refrigeration system cascaded with vapour compression refrigeration system and highest exergetic efficiency is also observed by using R141b and lowest was found by using R744 refrigerant.

(viii) The second law efficiency (exergetic efficiency) was observed when NH_3H_2O vapour absorption refrigeration system cascaded with vapour compression refrigeration system 216.4% using R141b and 180.1%using R744 refrigerant

(ix) Enhancement in the second law efficiency (exergetic efficiency) was observed when half effect Li/Br vapour absorption refrigeration system cascaded with vapour compression refrigeration system 73.65% using R141b and 24.97% using R744 refrigerant

(x) Enhancement in the second law efficiency (exergetic efficiency) was observed when single effect vapour absorption refrigeration system cascaded with vapour compression refrigeration system 139.41% using R141b and 93.8% using R744 refrigerant

(xi) Enhancement in the second law efficiency (exergetic efficiency) was observed when double effect vapour absorption refrigeration system cascaded with vapour compression refrigeration system 98.16% using R141b and 52.41% using R744 refrigerant

(xii) Enhancement in the second law efficiency (exergetic efficiency) was observed when triple effect vapour absorption refrigeration system cascaded with vapour compression refrigeration system 111.15% using R141b and 69.72% using R744 refrigerant in the vapour compression system.

(xiii) The exergy destruction ratio based on exergy of product is 78% using R141b and 74 % using R744 refrigerant in NH_3H_2O system.

(xiv) The exergy destruction ratio based on exergy of product is in the triple effect vapour absorption cascaded with vapour compression system using R141b is 68.9 % and 53.765% using R744 refrigerant.

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