e-ISSN: 2455-7013
Asian Journal of Management, Engineering & Computer Sciences (AJMECS)
Vol. 5(2), April 2020: 1-6
URL: http://www.crsdindia.com/ajmecs.html
Email: crsdindia@gmail.com

RESEARCH PAPER

Performance Evaluation of Ejector Refrigeration Systems (ERS) Using Low GWP Refrigerants

Radhey Shyam Mishra
Department of Mechanical, Production, Industrial & Automobiles Engineering,
Delhi Technological University, Delhi
Email: rsmishra@dtu.ac.in

ABSTRACT

Presently, the refrigeration and air conditioning is observing for energy efficient technologies which will decrease the electric power consumption from producing the damage to the environment. The ejector refrigeration system is originated to be energy efficient system which will be able to deliver the cooling by using the environment friendly refrigerants. In this paper HFO refrigerants are used in ejector refrigeration system and comparison were made with other HFC and HCFC refrigerants.

Key words: *Energy-Exergy analysis, Ejector refrigeration system, Thermodynamic performance-evaluation*

Received: 6th Jan. 2020, Revised: 28th Jan. 2020, Accepted: 11th Feb. 2020

How to cite this article:
Mshra R.S. (2020): Performance Evaluation of Ejector Refrigeration Systems (ERS) Using Low GWP Refrigerants. AJMECS, Vol. 5(2): April, 2020: 1-6.

INTRODUCTION

In the context of recent developments in the field of energy, the aspect related to energy consumption is of extreme importance for specialists. Many industries faith on refrigeration technologies, an extreme challenge being specified in energy savings. In this respect, efforts oriented towards efficient refrigeration systems have revealed the necessity of a proper design. The most commonly used method of cooling is based on vapor compression cycles.

Ejector refrigeration technology is the one which can utilize the waste heat to compress the refrigerant instead of compressor. Therefore electrical energy was saved which can employ to meet the other demand. When ejector is combined with vapour compression refrigeration system, then system will use a reduced amount of compressor power to provide the natural cooling of products.

EJECTOR REFRIGERATION SYSTEM

In the vapour compression refrigeration system, throttle device is used to increase the refrigeration effect from high pressure prevailing in the condenser to low pressure evaporator. Capillary tube and thermostatic expansion valve, used in the throttling devices in the vapour compression refrigeration system has highly irreversible process which causes more amount of wastage of the kinetic energy of the refrigerant. Vapour compression refrigeration systems uses CFCs, HFCs and HCFC refrigerants and their leakage from the system causes emissions in the environment hence degrading its air quality. This emission can be direct emission or indirect or both. Therefore energy efficient technologies which reduced the electric power consumption apart from the causing the damage to the environment. Ejector refrigeration system is a energy efficient device which is able to compress the refrigerant in the system and providing the cooling by utilizing the environment friendly refrigerant.

Kornhauser (1990) analyzed thermodynamic performance of the ejector-expansion refrigeration cycle on constant mixing pressure using R12 and found 21% improvement in COP. Da-Wen Sun(1998) described a new integrated refrigeration cycle based on the combination of an ejector cycle with a vapour compression cycle for maximizing performance of the conventional ejector cycles and providing high COP for refrigeration and observed that this cycle has a significant increase in system performance over the conventional systems and its COP values are competitive to the absorption machines. In this modified system, the waste heat was used and, higher COP value was observed. The system performance can be further improved if dual refrigerants are used.

Disawas and Wongwishes (2004) have carried out experimental investigation on two phase ejector as expansion device using R134a and R12 refrigerants and observed the COP improvement at lower sink temperature because motive mass flow rate is highly dependent on heat sink temperature.

Yapici and Ersoy (2005) had compared the thermodynamic performance of constant pressure and constant area mixing ejector using HR123 refrigerant and found the optimum coefficient of performance and area ratio determined by using the constant area flow model are greater than those of constant pressure model.

Yari and Sirousazar (2007) carried out the first and second law (exergy) analysis of the ejector-vapour compression refrigeration cycle using internal heat exchanger and intercooler for enhancing the performance of the cycle and investigated the effects of the evaporative and condenser temperatures on the coefficient of performance (COP), second law efficiency, exergy destruction rate and entrainment ratio and found that the COP and second law efficiency values of the new ejector-vapour compression refrigeration cycle are on average 8.6% and 8.15 % higher than that of the conventional ejector-vapour compression refrigeration cycle using R125. It was also observed that the COP of the new ejector-vapour compression cycle is 21 per cent higher than that of the conventional vapour compression cycle.

Chaiwongsa, *et al.,* (2007) have carried out experimental investigation on the effect of throat diameter of the nozzle on the performance on the refrigeration system using ecofriendly R134a refrigerant in the two phase ejector as expansion device and found maximum cooling capacity and COP at 0.8mm throat diameter by varying the dimension of nozzle diameter with cooling capacity.

Nehdi, *et al.,* (2007) carried out theoretical investigation on the performance of ejector-expansion refrigeration cycle with ecofriendly synthetic refrigerants and found maximum performance of 22% using R141b. Also investigated maximum first law performance (COP) using ejector as expansion device occurred at 9.9 area ratio and found best performance for using R141b and R408A for a given operating condition.

Bilr and Ersoy (2009) investigated theoretical improvement of ejector refrigeration cycle using two phase ejector using R134a refrigerant and observed that COP increases with decreasing evaporator temperature and also by increasing condenser temperature.

Sarkar, *et al.,* (2010) carried out optimization of geometric parameters of the ejector expansion refrigeration cycle using natural refrigerant (R717) and hydrocarbon (R600a and R290) refrigerants and observed 21.55% maximum COP improvement using isobutene (R600a), 18% using propane (R290) 12% using ammonia(R717).

Yin-Hai Zhu & Peixue Jiang (2012) developed refrigeration system which combines a basic vapour compression refrigeration cycle with an ejector cooling cycle. The ejector cooling cycle is driven by the waste heat from the condenser in the vapor compression refrigeration cycle. The additional cooling capacity from the ejector cycle is directly input into the evaporator of the vapor compression refrigeration cycle. The governing equations are derived based on energy and mass conservation in each component including the compressor, ejector, generator, booster and heat exchangers. The system performance was analyzed for the design conditions and found that the COP is improved by 9.1% for R22 system.

Chen, *et al.,* (2014) studied theoretically, the application of different nine working fluids in the ejector vapour refrigeration system and found the R600 gives higher first law efficiency (COP) of ejector refrigeration system.

Li, *et al.,* (2014) had compared thermodynamic performance characteristics of ejector expansion refrigeration cycle using R1234yf and R134a as a refrigerants and found that R1234yf gives better performance than R134a at 40°C of condenser temperature and 5°C of evaporator temperature.

Chen, *et al.,* (2015) had performed exergy analysis of a ejector refrigeration system using ecofriendly R134a refrigerant and found that by reducing the exergy destruction in the parts improves the quality of exergy analysis in terms of exergetic efficiency and concluded the maximum exergy destruction in ejector followed by generator and evaporator and tried for reducing ejector exergy destruction by improving the ejector efficiencies. Similarly generator (boiler) exergy destruction can be reduced by improving design of other components of the system.

Memet and Preda, (2015) carried out theoretical analysis of ejector refrigeration system using R134a and found that when by increasing the generating temperature, the coefficient of performance(COP) is increasing together and the best COP value being 0.178 also the generating temperature increase leads to the increase of the work input to the pump.

Saleh, *et al.,* (2016) had numerical investigated parameter analysis of ejector refrigeration cycle with different refrigerants using ejector refrigeration cycle and found best thermodynamic performance using R245fa

Lot of work has been done by several investigators using CFCs, HFCs, natural and hydrocarbon refrigerants in the ejector refrigeration systems and still very less work has been done using HFO refrigerant. In this paper the utility of HFO refrigerants in ejector refrigeration system are highlighted for improving thermodynamic performances.

RESULTS AND DISCUSSION

Table- 1 shaows the numerical values have been chosen for numerical computation.

Table- 2 shows the variation of first law efficiency (COP) and variation of Entrainment Ratio of vapour compression refrigeration system using ejector using ecofriendly refrigerants and it was observed that maximum COP was observed by using R1234ze(Z) and minimum by using R123. However maximum Entrainment Ratio was observed by using HFO-1336mzz(Z) and minimum by using R125. Similarly maximum second law efficiency and maximum compression Ratio was observed by using R-1225ye(Z).

Table 1: Input data used in the ejector refrigeration system using ecofriendly refrigerants

Input data	Ejector geometric input
Cooling Load of ejector refrigeration system (Qeva) =4.75 "kW"	{Length / Diameter} ratio of constant area mixing chamber(L/D) of ejector =10
Boiler temperature ejector refrigeration (T_{boiler}) =333(K)	Diameter of primary nozzle throat (D_throat)metre =(0.5/1000)
Evaporator temperature of ejector refrigeration (T_eva) =273(K)	Diameter of mixing chamber(D_m) metre =(1.4/1000)
Condenser temperature of ejector refrigeration (T_cond) =303(K)	Exit diameter of primary nozzle (D_p) metre =(0.8/1000)
Ambient temperature (To) =300(K)	Diffuser angle(theta) =3°
Refrigerant used in ejector refrigeration system =R1243zf	Diffuser Length (L_d) metre =(112/1000)
	Area Ratio =7.84

Table 2: Effect of ecofriendly refrigerants on the variation of thermal performance parameters of vapour compression refrigeration system using ejector

Refrigerant	COP	EDR	Second law Efficiency	Entrainment Ratio(shy)	Compression Ratio	Constant used for COP	a	b
R-1234ze(Z)	6.483	4.007	0.1997	1.454	1.942	7.089	2.072	1.02
R-1234ze(E)	6.213	3.56	0.2193	1.383	1.970	6.804	1.963	1.03
HFO-1336 mzz(Z)	4.723	3.573	0.2187	1.535	2.347	5.328	2.134	0.9652
R-1243zf	6.016	3.754	0.2103	1.359	1.807	6.543	1.904	1.035
R1234yf	5.788	3.298	0.2327	1.353	1.987	6.313	1.891	1.033
R-1233zd(E)	5.799	3.833	0.2069	1.477	2.07	6.403	2.097	1.022
R-1224yd(Z)	5.163	3.468	0.2238	1.467	2.229	5.714	2.063	0.9902
R-1225ye(Z)	5.734	3.212	0.2374	1.386	2.151	5.858	1.933	1.016
R-124	5.333	3.256	0.2349	1.396	2.162	5.827	1.959	1.011
R123	5.141	3.545	0.220	1.496	2.254	5.648	2.092	0.9832

Table- 3 shows the variation of first law efficiency (COP), Exergetic efficiency and Compression Ratio of ejector coupled vapour compression refrigeration system using HFO-1243zf with variation of boiler temperature and it was observed that boiler temperature is increasing, condenser temperature is increasing, first law efficiency (COP) and second law efficiency (Exergetic efficiency) is decreasing. Similarly that boiler temperature is increasing; Compression Ratio of ejector coupled vapour compression refrigeration system is decreasing.

Table 3: Variation with Generator (Boiler) temperature of ejector fitted vapour compression refrigeration system using R1243zf

$T_{\_Boiler}$ (K)	Exergetic efficiency	Exergy destruction Ratio (EDR)	Entrainment Ratio	Compression Ratio	a	b
333	0.2103	3.754	1.359	1.665	1.398	0.6952
338	0.2.091	3.782	1.359	1.627	1.449	0.7046
343	0.2080	3.807	1.359	1.593	1.497	0.7132
348	0.2071	3.829	1.359	1.563	1.542	0.7218
353	0.2062	3.848	1.359	1.537	1.582	0.7296
358	0.2056	3.863	1.359	1.514	1.619	0.7373
363	0.2053	3.871	1.359	1.495	1.648	0.7444

Table- 4 shows the variation of first law efficiency (COP), exergetic efficiency, entrainment ratio and compression ratio of ejector coupled vapour compression refrigeration system using HFO-1243zf with variation of condenser temperature and it was observed that condenser temperature is increasing, second law efficiency (Exergetic efficiency) is increasing. Similarly entrainment ratio is also increasing while exergy destruction ratio is decreasing.

Table- 5 shows the variation of first law efficiency (COP), second law efficiency (exergetic efficiency) of ejector coupled vapour compression refrigeration system using HFO-1243zf with variation of evaporator temperature and it was observed that evaporator temperature is increasing, first law efficiency (COP)and second law efficiency (exergetic efficiency) is decreasing and entrainment ratio is also increasing.

Table 4: Variation with condenser temperature with first law efficiency (COP), exergetic efficiency, entrainment ratio and compression ratio of ejector fitted vapour compression refrigeration system using R1243zf

$T_{\_Cond}$ (K)	COP	EDR	Exergetic efficiency	Entrainment Ratio	Compression Ratio	Constant used for COP	a	b
300	1.363	3.701	0.2127	1.663	1.807	1.486	1.582	0.8595
303	0.9115	3.676	0.2138	1.807	1.807	0.9951	1.489	0.8092
306	0.6283	3.651	0.2149	1.961	1.807	0.6867	1.413	0.7676
308	0.4595	3.634	0.2158	2.069	1.807	0.5376	1.368	0.7436
309	0.4337	3.625	0.2162	2.124	1.807	0.4746	1.348	0.7326

Table 5: Variation with evaporator temperature with first law efficiency (COP), exergetic efficiency, entrainment ratio and compression ratio of ejector fitted vapour compression refrigeration system using R1243zf

$T_{\_EVA}$ (K)	COP	EDR	Exergetic efficiency	Entrainment Ratio	Compression Ratio	Constant used for COP	a	b
268	0.3692	1.613	0.3826	3.002	1.602	0.4163	1.359	0.6478
273	0.4888	1.988	0.3347	2.517	1.665	0.5451	1.398	0.6952
278	0.6556	2.583	0.2791	2.126	1.732	0.7233	1.441	0.7483
283	0.9115	3.676	0.2138	1.807	1.807	0.9950	1.489	0.8092

CONCLUSIONS

Following conclusions were drawn from this investigation-

1. Optimum (maximum) coefficient of performance (first law efficiency) of ejector coupled vapour compression refrigeration system using HFO-1234ze(Z) while maximum exergetic efficiency (i.e. second law efficiency) was observed by using R-1225ye(Z).
2. Maximum entrainment ratio of ejector coupled vapour compression refrigeration system was observed by using HFO-1336mzz(Z) and minimum by using R125.
3. Maximum Effectiveness of ejector coupled vapour compression refrigeration system was observed by using R-1225ye(Z)
4. When generator temperature of ejector coupled vapour compression refrigeration system is increasing, exergetic efficiency (i.e. second law efficiency) is decreasing.
5. When generator temperature of ejector coupled vapour compression refrigeration system is increasing, compression ratio of ejector coupled vapour compression refrigeration system is decreasing.
6. When condenser temperature of ejector coupled vapour compression refrigeration system is increasing, second law efficiency (exergetic efficiency) is increasing. Similarly entrainment ratio is also increasing while exergy destruction ratio is decreasing condenser temperature of ejector coupled vapour compression refrigeration system using R1243zf is increasing, first law efficiency (COP) is decreasing.
7. When evaporator temperature of ejector coupled vapour compression refrigeration system using HFO-1243zf is increasing, coefficient of performance (COP) is decreasing and entrainment ratio is also increasing.
8. When evaporator temperature of ejector coupled vapour compression refrigeration system using HFO-1243zf is increasing, exergetic efficiency is decreasing.

REFERENCES

1. Bilr N. and Ersoy H.K. (2009): Performance improvement of the vapour compression refrigeration cycle by a two phase constant area ejector. International Journal of Energy Research, 33(5): 469-480.
2. Chaiwongsa P. and Wongwishes S. (2007): Effect of throat diameters of the ejector on the performance of the refrigeration cycle using two phase ejector as an expansion device. International Journal of Refrigeration, 30(4): 601-608
3. Chen J., *et al.,* (2014): screening of working fluids for the ejector refrigeration system. International Journal of Refrigeration, 47: 1-14.
4. Chen J., *et al.*, (2015.b): conventional and advanced exergy analysis of an ejector refrigeration system. Applied Energy, 44: 139-151.
5. Da-Wen Sun (1998): Evaluation of a combined ejector–vapour-compression refrigeration system. International Journal of Energy Research, 22(4): 333-342.
6. Disawas S. and Wongwishes S. (2004): Experimental investigation on the performance of the refrigeration cycle using two phase ejector as expansion device. International Journal of Refrigeration, 27(6): 587-594.
7. Kornhauser A.A. (1990): the use of an ejector as a refrigerant expander. Proceedings of the USN/ IIR-Purdue Refrigeration Conference, page-10-19.
8. Li H., *et al.,* (2014): Performance characteristics of R1234yf ejector expansion refrigeration cycle. Applied Energy, 121: 96-103
9. Memet F. and Preda A. (2015): An analysis of the performance of an ejector refrigeration cycle working with R134a IOP. Conference Series: Materials Science and Engineering, Volume 95, Modern Technologies in Industrial Engineering Romania (Mod Tech-2015), 17-20.
10. Nehdi E., *et al.,* (2007): Performance analysis of the vapour compression cycle using ejector as an expander. International Journal of Energy Research, 31(4): 364-375.
11. Saleh B. *et al.,* (2016): Performance analysis and working fluid selection for ejector refrigeration cycle. Applied Thermal Engineering, 107: 114-124.
12. Sarkar J, *et al.,* (2010): Geometric parameter optimization of ejector-expansion refrigeration cycle with natural refrigerants. International Journal of Energy Research, 34(1): 84-94
13. Yapici R. and Ersoy H.K. (2005): Performance characteristics of the ejector- expansion device. Energy conversion and Management, 46(18-19): 3117-3135.
14. Yari M. and Sirousazar M. (2007): Performance analysis of the ejector-vapour compression refrigeration cycle. Institute of Mechanical Engineers, https://doi.org/10.1243/09576509JPE484
15. Yin-Hai Zhu and Peixue Jiang (2012): Hybrid vapor compression refrigeration system with an integrated ejector cooling cycle. International Journal of Refrigeration, 35(1): 1-18.