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Ejector - Expansion Vapor Compression Refrigeration Cycle for Application in Domestic Refrigerator: A Review

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***Abstract:* A review on ejector expansion vapor compression refrigeration cycle (EVRCS) applied in a domestic refrigerator. Mostly refrigerator is working on vapor compression refrigeration cycle, for domestic purpose there requires increasing the performance of that system. Ejector is used as an expansion device which gives better performance than the vapor compression cycle. In this study, R600a refrigerant is used in ejector expansion vapor compression refrigeration cycle. The result shows that the system coefficient of performance is higher than conventional vapor compression cycle. The compressor work of EVRCS reduces than the VCRS and pressure ratio is also reduced. If diffuser design can modified and increase inlet compressor pressure it reduces compressor work and entrainment ratio is increased by some modified mechanism than refrigerating effect also increases.**

IndexTerms- Refrigerator VCRS, Ejector, Single Phase Ejector,

1. INTRODUCTION

Refrigeration may be defined as lowering the temperature of an enclosed space by removing heat from that space and transferring it elsewhere. Ideal vapor compression refrigeration cycle results, by eliminating impracticalities associated with reversed Carnot cycle such as vaporizing the refrigerant completely before compression, replacing turbine with throttling device (expansion valve or capillary tube).Generally, domestic and industrial refrigerator, air conditioning system, heat pump and water cooler designed based on vapor compression refrigeration cycle. The refrigerator is among the home appliances that use the most energy.Recent studies in the area of refrigeration cycles, with regard to the search for more efficient systems, have concentrated their efforts mainly in two specific areas: the development of new technologies, using alternative cycles to obtain a better performance and the use of new refrigerants, pure or mixtures, aiming both energetic and environmental aspects. Different alternative cycles have been studied and there are many promising options to increase the thermodynamic efficiency when compared to the traditional vapor compression cycle. Currently, some of the most explored alternative refrigeration cycles are: ejector refrigeration, cascade and refrigerant injection systems.

Ejector-expansion is recognized as a potential method of improving the performance of vapor-compression refrigeration cycle by the recovery of the expansion work normally lost in the expansion valve or capillary tube.

(a) (b)

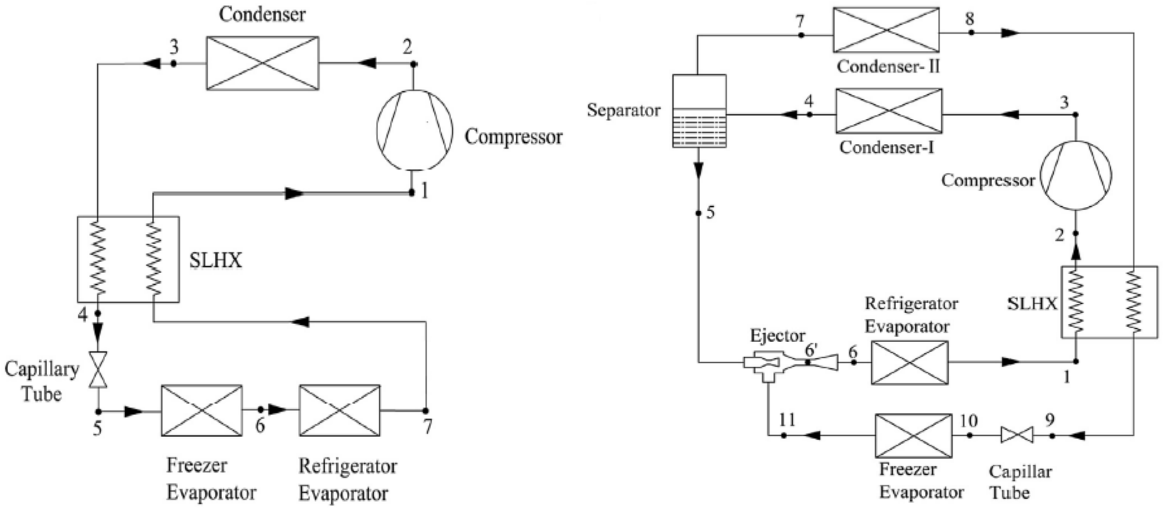

Figure 1- (a) Traditional VCR,(b) VCRS with ejector [3]

1.1 Ejector vapor compression refrigeration cycle

A schematic diagram of a traditional vapor compression refrigeration cycle (TVRC) with single refrigerant loop for domestic refrigerator/freezers is shown in Fig 1(a). It mainly consists of five basic components: a compressor, a condenser, a suction line heat exchanger (SLHX), a capillary tube, and two evaporators in series (one for the freezer compartment and the other for the refrigerator compartment).

The compressed mixture vapor of refrigerant (state point 3) is partially condensed (state point 4) in condenser-I; and then the two-phase refrigerant is separated in the phase separator (process 4-5 and process 4-7); the vapor refrigerant with more composition is totally condensed in condenser-II (state point 8); further, the condensed fluid is transferred to the freezer evaporator (FE) through the SLHX and the capillary tube (process 8-9-10-11); on the other hand, the liquid refrigerant with more composition from the phase separator is the primary fluid of the ejector to entrain the vapor (secondary fluid) from the FE (state point 11); at last, the mixed fluid (state point 6) flows through the refrigerator evaporator (RE), the SLHX and the compressor successively (process 6-1-2-3).Using an ejector can recover the energy loss in the throttling process and raise the evaporating pressure in the RE, i.e. compressor suction pressure. Consequently, the compression ratio can be reduced, resulting in higher energy efficiency of the VERC cycle.

2. LITERATURE SURVEY:

In past years lot of studies made on VCRS with ejector and different design are proposed in that survey.

Mengliu Zhou et.al, [1] had studied a novel dual-nozzle ejector enhanced refrigeration cycle is presented for dual evaporator household refrigerator-freezers. The proposed ejector equipped with two nozzles can efficiently recover the expansion work from cycle throttling processes and enhance cycle performances. The performances of the novel cycle are evaluated by using the developed mathematical model, and then compared with that of the conventional ejector enhanced refrigeration cycle and basic vapor-compression refrigeration cycle. The simulation results show that for the given operating conditions, the coefficient of performance (COP) of the novel cycle using refrigerant R134a is improved by 22.9–50.8% compared with that of the basic vapor-compression refrigeration cycle, and the COP improvement is 10.5–30.8% larger than that of the conventional ejector enhanced refrigeration cycle.

Xiao Wang, et.al, [2] had studied an experimental investigation on two-phase driven ejector performance characteristics in a novel ejector enhanced refrigeration system (NERC). An experimental setup using refrigerant R600a is designed and built based on the NERC system. In the experimental setup, the ejector uses two-phase refrigerant coming from the high-temperature evaporator as the primary fluid. The experiments are carried out to examine the influences of the main operational and geometric parameters, including the primary fluid pressure, the secondary fluid pressure, the NXP (motive nozzle exit position) and the nozzle throat diameter. The pressure lift ratio increases with the pressure and quality of the primary fluid and the nozzle throat diameter, decreases with the secondary fluid pressure and the NXP. For the overall ejector efficiency, the primary fluid pressure is the most important parameter based on the ejector efficiency evaluation. After that, the primary fluid quality, the nozzle throat diameter and the secondary fluid pressure have relatively smaller effects on the ejector efficiency. The ejector efficiency dependency on the NXP is the lowest. The ejector efficiency has corresponding maximum values with increasing pressure and quality of the primary fluid and the nozzle throat diameter. The aim of this study is to provide some guidelines for optimization design of the two-phase driven ejector and it is hoped to further the development of energy saving potential by ejector-expansion technology in refrigeration systems.

Xiaoqin Liu, et.al, [3] had studied a modified vapour-compression refrigeration cycle (MVRC) for applications in domestic refrigerator/freezers using zeotropic mixture R290/R600a. In the MVRC cycle, an ejector and a phase separator are added based on a traditional vapour-compression refrigeration cycle (TVRC) to improve the cycle performance. The coefficient of performance COP, volumetric cooling capacity, exergy loss and exergy efficiency are theoretically investigated for the MVRC cycle and compared with the TVRC cycle. The COP and volumetric cooling capacity can be improved maximally by 16.71% and 34.97%, respectively. The exergy efficiency can be raised maximally by 6.71% and the total exergy loss can be reduced maximally by 24.47%.

Meibo Xing, et.al, [4] had studied a novel vapor-compression refrigeration cycle with mechanical subcooling using an ejector is proposed to improve the performance of a conventional single-stage vapor-compression refrigeration cycle. In the theoretical study, a mathematical model is developed to predict the performance of the cycle by using R404A and R290, and then compared with that of the conventional refrigeration cycle. When the evaporator temperature ranges from -40 to -10 ^{0}C and the condenser temperature is 45 ^{0}C, the novel cycle displays volumetric refrigeration capacity improvements of 11.7% with R404A and 7.2% with R290. And the novel cycle achieves COP improvements of 9.5% with R404A and 7.0% with R290. In addition, the improvement of the COP and cooling capacity of this novel cycle largely depends on the operation pressures of the ejector.

Huashan Liet.al, [5] had studied a constant-pressure mixing ejector, the performance characteristics of an ejector-expansion refrigeration cycle (EERC) using R1234yf as refrigerant have been investigated. Also, the performance of R1234yf and R134a in the EERC has been compared. The study shows that, at condensing temperature of 40 ^{0}C and evaporation temperature of 5 ^{0}C, the coefficient of performance (COP) and volumetric cooling capacity (VCC) of the R1234yf EERC peak up to 5.91 and 2590.76 kJ/m3, respectively. Compared with R134a, although the R1234yf EERC has lower COP and VCC, it offers greater COP and VCC improvement potential. Also, it is found that the ejector design parameters including the pressure drop in suction nozzle, area ratio and component efficiencies have a considerable effect on the R1234yf EERC performance.

NagihanBilir et.al, [6] had studied the performance of a vapour compression system that uses an ejector as an expansion device was investigated. In the analysis, a two-phase constant area ejector flow model was used. R134a was selected as the refrigerant. As the difference between condenser and evaporator temperatures increases, the improvement ratio in COP rises whereas ejector area ratio drops. If ejector is used as expander device when evaporator temperature changes from 5 ^{0}C down to -25 ^{0}C and condenser temperature changes from 35 to 50 ^{0}C, the minimum performance improvement ratio of the system becomes 10.1% whereas its maximum is 22.34%. Even under off-design operating conditions, the performance of an EERC is higher than the system without ejector.

Xiao Wang, et.al, [7] had studied EVRCs (ejector-expansion vapor-compression refrigeration cycles) applied in domestic refrigerator freezers have been concerned due to their potentials of improving cycle performance. Considering the limited capacity of the existing EVRCs to enhance cycle performance, we further present a novel MEVRC (modified EVRC), in which the use of the two-phase ejector to more efficiently recover the expansion work would significantly enhance the overall system performance. A mathematical model is developed to carry out comparative simulation studies between different EVRCs. According to the results of the simulation for the EVRCs using the refrigerant R600a, the MEVRC can reach a highest pressure lift ratio of the ejector and give most excellent performance improvements in the COP (coefficient of performance) and the volumetric refrigeration capacity compared with the other EVRCs.

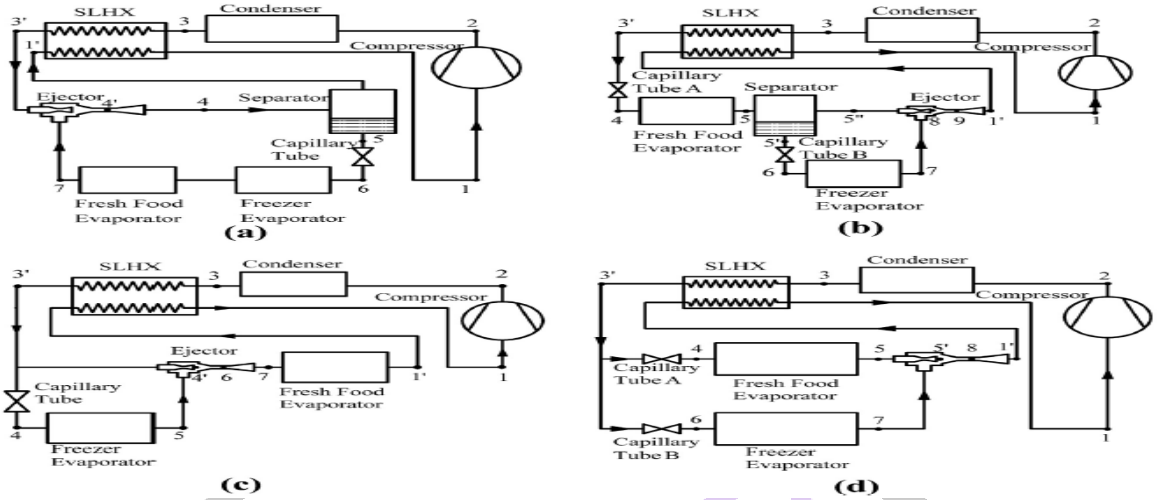

Fig 2.1 Schematic diagram for four EVRCS [7]

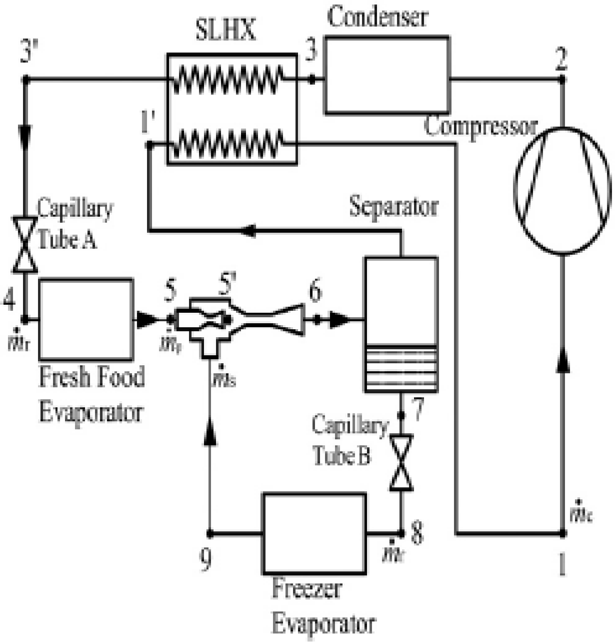

Fig 2.2 Schematic diagram of MEVRC [7]

MortazaYari et.al, [8] had studied two new CO2 cascade refrigeration cycles are proposed and analysed. In both these cycles the top cycle is an ejector-expansion transcritical cycle and the bottom cycle is a sub-critical CO2 cycle. The range of increase in COP is about 10.8-17.2% and 18-31.5% compared to that of the cascade TRCC cycle without ejector, respectively. Compared to the two-stage inter-cooling cycles reported in the literature, reasonable values of COP are obtained for the proposed cycles. The compressor discharge temperature of the proposed cycles however, is much less than those of the two stage inter-cooling cycles reported in the literature.

JaharSarkar[9] had studied Thermodynamic analyses and comparison of ammonia, propane and isobutene based vapour compression refrigeration cycles are presented in this article using constant area mixing ejector as an expansion device. Optimization of ejector geometric parameter based on the maximum cooling COP and performance improvement for different operating conditions is studied. Study shows that the optimum parameters as well as COP improvement using ejector as expansion device are strongly dependent on the refrigerant properties as well as the operating conditions. The optimum geometric parameter is maximum for ammonia, whereas minimum for isobutene. Using ejector as an expansion device, isobutene yields maximum COP improvement of 21.6% followed by propane (17.9%) and ammonia (11.9%) for studies ranges.

Suhas D Kshirsagar, et al. [10] had studied the ejector refrigeration and joined together vapor packing ejector refrigeration frameworks are exhibited. Additionally their working conditions and the coefficients of execution, got by different researchers‟ hypothetical and trial studies, are given. The criticalness of the working liquid in the execution of the framework is underlined in conjunction with the intercooler, which permits the utilization of two separate refrigerants at once in the plane and compressor subsystems. Looking proper refrigerants, some hypothetical and trial studies demonstrate the points of interest of utilizing R134a within these frameworks. Nonetheless, the utilization of hydrocarbon refrigerants like isobutene (R600a) is proposed as a decent choice, in spite of the fact that examination and some wellbeing systems need to be produced before applying these "nature friendly" refrigerant.

H. KursadErsoy, et.al, [11] had studied the use of an ejector as an expansion device instead of an expansion valve for expansion work recovery in a vapor-compression cycle was experimentally investigated. The coefficient of performance (COP) values for both conventional and ejector systems were experimentally investigated under the same external conditions. Depending on the operating conditions, it was found that the work recovery in the ejector was between 14% and 17%. It was also found that the refrigeration system with an ejector as the expander exhibited a COP that was 6.2%–14.5% higher than that of the conventional system. The experimental results were found to comply with the theoretical results within an error of approximately 10%.

B.O. Bolaji [12]had studied an experimental study of R152a and R32, environment-friendly refrigerants with zero ozone depletion potential (ODP) and low global warming potential (GWP), to replace R134a in domestic refrigerator. A refrigerator designed and developed to work with R134a was tested, and its performance using R152a and R32 was evaluated and compared with its performance when R134a was used. The results obtained showed that the design temperature and pull-down time set by International Standard Organisation (ISO) for small refrigerator were achieved earlier using refrigerant R152a and R134a than using R32. The average coefficient of performance (COP) obtained using R152a is 4.7% higher than that of R134a while average COP of R32 is 8.5% lower than that of R134a. The system consumed less energy when R152a was used. The performance of R152a in the domestic refrigerator was constantly better than those of R134a and R32 throughout all the operating conditions, which shows that R152a can be used as replacement for R134a in domestic refrigerator.

Jianlin Yu, et,al, [13] had studied A new ejector refrigeration system (NERS) with an additional liquid–vapor jet pump was proposed. The jet pump was used to decrease the backpressure of the ejector, and then the entrainment ratio and the coefficient of performance (COP) of the new system could be increased. The theoretical analysis and simulation calculation was carried out for the new system. When generating temperature, condensing temperature, evaporating temperature and cooling capacity are kept unchangeable, as backpressure of ejector drops, generator heat load decreases, pump work increases and COP increasees. And when backpressure changes the COP of NERS can vary in a wide range and increase by one time compared with CERS. NERS improves its COP at the cost of more pump work. However, in the point of view of exergy the new system is much better. For example, in the foregoing operating condition, when Pb = 6.7 bar, NERS can save 23% input exergy for R134a and 16% input exergy for R152a.

Md. EzazAhammed,et.al, [14] had studied A two phase ejector suitable as an expansion device in a CO2 based transcriticalvapour compression refrigeration system is designed by extending the thermodynamic analysis and by interfacing with the system simulation model. A converging diverging nozzle is considered as primary nozzle of the ejector. Parameters such as COP, entrainment ratio, pressure lift and cooling capacity were obtained for varying motive inlet and evaporator conditions. Motive inlet is found to be crucial for both performance and range of feasible application. Results show a COP improvement of 21% compared to an equivalent conventional CO2 system.

J. Garcı´a del Valle, et.al, [15] had studied an investigation of an ejector refrigeration system working with refrigerant R-134a, aiming at the enhancement of the pressure recovery. The critical condition has been determined for three mixing chambers of equal internal diameter but different profiles and for several stagnation conditions of primary and secondary fluid. Preliminary results have shown that the stagnation degree of superheating for both primary and secondary flows does not affect the mass ratio for values higher than 10 ^{0}C. it has been found that, for a wide range of nozzle positions, the mass ratio remains approximately constant for mixing chamber “A” whereas for the geometries “B” and “C”, the mass ratio depends on the nozzle position.

Fang Liu, et al. [16] had studied a technique for deciding inside ejector segment efficiencies utilizing a two-stage stream ejector model. The measured execution information outside to the ejector in conjunction with the ejector model was utilized to focus the isentropic efficiencies of the intention and suction spouts, and the effectiveness of blending area. It was discovered that ejector segment efficiencies fluctuate with ejector geometries and working conditions, which are not the same as the steady efficiencies expected by past scientists. The efficiencies of the controllable ejector thought process spout, suction spout and blending segment range from 0.50 to 0.93, from 0.37 to 0.90, and 0.50 to 1.00, separately, in Co2 refrigeration cycles under diverse working conditions. Observational connections were made and joined into a Co2 air molding framework model to gauge ejector part efficiencies at distinctive ejector geometries and working conditions.

MahmoodMastaniJoybari et.al, [17] had studied exergy analysis was applied to investigate the performance of a domestic refrigerator originally manufactured to use 145 g of R134a. It was found that the highest exergy destruction occurred in the compressor followed by the condenser, capillary tube, evaporator, and superheating coil. Taguchi method was applied to design experiments to minimize exergy destruction while using R600a. Taguchi parameters were selected by the obtained results from R134a and an experiment using 60 g of R600a, which indicated similar results as R134a. Based on the outcomes, R600a charge amount, condenser fan rotational velocity and compressor coefficient of performance were selected for the design. The analysis of variance results indicated that R600a charge amount was the most effective parameter. At the optimum condition, the amount of charge required for R600a was 50 g, 66% lower than R134a one, which not only brings economic advantages, but also significantly reduces the risk of flammability of the hydrocarbon refrigerant.

J.U. Ahamed, et.al, [18] had studied the possibilities of researches in the field of exergy analysis in various usable sectors where vapor compression refrigeration systems are used. Nowadays, hydrocarbons are considered as refrigerant having low ODP and GWP, and these are considerable in the aspect of exergy analysis. Refrigerants R 407a, R 600a, R 410a and R 134a are considered and analyzed with respect to exergy efficiency. Mixtures of hydrocarbons with R134a also show better performance with respect to other refrigerants. Exergy efficiency can be improved by sub-cooling up to 5 ◦C and reducing the temperature difference of the evaporating and condensing temperature. It can be increased by increasing reference temperature also.

3. Conclusion:

In general, utilization of an ejector in vapor compression refrigeration cycle can be viewed as an appealing choice for enhancing cycle execution. Particularly, it shows a remarkable legitimacy in diminishing the pressure proportion and also in expanding the COP when worked at lower refrigerating temperature.

Use of ejector in vapour compression cycle of domestic refrigerator gives higher coefficient of performance and reduces compressor work, pressure ratio, than conventional vapour compression cycle.

Refrigerator performance can be increased by different ejector design connect to that system and gives better performance and also increase the cop, and reduce the compressor work.

From late studies that can be seen hydrocarbons working liquids can be a decent specialized and natural alternative for ejector pressure frameworks in spite of the fact that they will oblige painstakingly created security conventions because of their flammability**.**

From exergy analysis was applied to investigate the performance of a domestic refrigerator originally manufactured to use 145 g of R134a. R600a refrigerant require 66% less charge amount than R134a refrigerant in domestic refrigerator which not only brings economic advantages, but also significantly reduces the risk of flammability of the hydrocarbon refrigerant.The higher COP in the ejector system is attributed to the ejector and separator. Because of expansion work was recovered in the ejector. In the separator, only the saturated liquid was sent to the evaporator. Hence, the evaporator had a higher performance, and the pressure drop decreased. These two positive effects provided by the ejector and separator resulted in the ejector system exhibiting less compressor work than the conventional system. So coefficient of performance is increase of the vapour compression refrigeration system with ejector.

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