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Experimental Analysis of Refrigeration Ejector System by using Different Organic Refrigerants

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Abstract: This paper presents the experimental analysis performed on ejectors to optimize operating conditions like evaporator temperature, condenser temperature and generator temperature. Using the environmentally friendly working fluid R134a, R152a, R600a, R717 (Ammonia). Parametric analysis was performed to review the effect of blending chamber geometry on ejector performance which has direct impact on coefficient of performance of ejector refrigeration cycles. Results show that operating conditions and thus the effect of the deflection of the primary flow on the secondary flow is set. CFD simulations was performed to identify optimum geometry and optimum operating condition
Keywords: Ejector, CFD, Refrigerants, Ejector Refrigeration cycle, Entrainment Ratio.

I. INTRODUCTION

This Ejectors are utilized in several different engineering applications and have several advantages over conventional compression systems. These include no moving parts within the compressor (except the pump) and hence no requirement for lubrication. The relatively low cost of capital, simplicity of operation, reliability and really low maintenance cost are other advantages Low power consumption compares to compressor. It also can be wont to recover the waste heat from industrial processes, which helps to mitigate the issues associated with CO2 emission and to scale back the value. The ejector design are often classified into two categories according to the position of the nozzle for the nozzle with its exit located within the constant-area section of an ejector, the blending of the primary and thus the before the entrained flows occurs inside the constant-area section and therefore the ejector is known as "constant-area mixing ejector" For the nozzle with its exit located within the suction chamber which is before the constant-area section, the ejector is referred as "constant-pressure mixing ejector" Therefore, most of current studies about ejector are focused on the constant-pressure mixing ejector. The primary type is to assume that the blending pressure is adequate to the evaporator pressure [17], the second is to assume that the pressure drop by the receiving section of the ejector may be a constant value Third is to optimize the blending pressure by calculation CFD tools have been proved to be valuable tools for understanding and analyzing complex fluid flow problems, such as the entrainment and mixing processes in ejectors. It was concluded that, surely conditions, simulated results were in excellent agreement with measured data. However, the selection of air as a working fluid and other test conditions weren't very fortunate, especially when a cooling cycle cares. The ejector design can be classified into two categories according to the position of the nozzle for the nozzle with its exit located within the constant-area section of an ejector, the mixing of the primary and the entrained flows occurs inside the constant-area section and the ejector is known as "constant-area mixing ejector". For the nozzle with its exit located within the suction chamber which is in front of the constant-area section, the ejector is referred as "constant-pressure mixing ejector". For this kind of ejector, it was assumed that the mixing of the primary and the entrained streams occurs in the suction chamber with a uniform or constant pressure. It is known that the constant-pressure ejector has a better performance than the constant-area ejector and is thus widely used.

II. LITERATURE REVIEW

Szabolcs Vargaa *et al* [1] Ejector efficiencies for the first nozzle, suction, mixing and diffuser were determined for the primary time, consistent with their definitions, using an axi-symmetric CFD model. Water was considered as working fluid. Ejector performance was estimated for various nozzle throat to constant section area ratios. The results indicated the existence of an optimal ratio, counting on operating conditions. Szabolcs Varga, *et al* [2] The CFD model was supported the axi-symmetric representation of the experimental ejector, using water as working fluid. The experimental entrainment ratio varied within the range of 0.1e0.5 counting on operating conditions and spindle tip position. it had been found that the first flow are often successfully adjusted by the spindle. CFD predicted the secondary flow and entrainment ratio with good accuracy only in 70% of the cases. Szabolcs Varga, *et al* [3] Working fluids were selected supported the standards of low environmental impact and good performance within the range of operating conditions. Numerical results clearly show adjusting spindle position resulted during a significant improvement of the entrainment ratio compared to a hard and fast geometry ejector. This increase in ejector performance was as high as 177% for low condenser pressures.

Keenan, J. H *et al* [4] Mixing of the first and secondary fluid takes place at constant pressure at the exit of the first nozzle. Both models presumes that the shock waves occur within the blending section thanks to the high-pressure region within the downstream. This 1-D constant pressure mixing theory is unable to research the choking of the entrained flow at critical mode operation. In practice two choking phenomenon exist within the ejector performance: one within the primary flow through the nozzle and second within the entrained flow. I. W. Eames, *et al* [5] Both the theoretical and experimental studies on the steam jet refrigerator, administered with boiler temperatures between 120 and 140C, and evaporator temperatures between 5 and 10 C, produced leads to which the consequences of varied parameters on the general operation were coherently illustrated. the general coefficient of performance of the cycle measured experimentally was, on the average , within 17% of the theoretical predictions. Such discrepancy was never worse than 30%, even near the outer bounds of the operating range.

B.J. Huang *et al* [6] A 1-D analysis for the prediction of ejector performance at critical-mode operation is administered within the present study. Constant-pressure mixing is assumed to occur inside the constant-area section of the ejector and therefore the entrained flow at choking condition is analysis. We also administered an experiment using 11 ejectors and R141b because the working fluid to verify the analytical results. The test results are wont to determine the coefficients, ηp, ηs, Øp and Øm defined within the 1-D model by matching the test data with the analytical results. it's shown that the1-D analysis using the empirical coefficients can accurately predict the performance of the ejectors.

Jianyong Chen *et al* [7] For an ejector cooling system , the working fluid significantly influences the ejector behavior and system performance also as ejector design. There are three categories of working fluids: wet fluids, dry fluids and isentropic fluids. Four wet fluids (R134a, R152a, R290 and R430A), four dry fluids (R245fa, R600, R600a and R1234ze) and one isentropic fluid (R436B). The consider paid to the superheat of the ejector primary flow. Excessive superheat of the ejector primary flow only slightly improves the entrainment ratio, and its effects on COP are insignificant. a rise within the excessive superheat leads to a decrease of Carnot efficiency. A minimum superheat is found, and it's hooked in to the used working fluid and therefore the operating temperatures also because the ejector nozzle efficiency. The comparison among these nine candidates indicates that R600 may be a good candidate for the ejector cooling system thanks to a comparatively high COP and its low environmental impact. Kanjanapon Chunnanond *et al* [8] This paper describes a basic background and development of an ejector and its application in refrigeration purposes. This paper describes a basic background and development of an ejector and its application in refrigeration purposes. two parameters, wont to express the system performance (entrainment ratio and important pressure), were also found to directly depend upon ejector geometries and its working fluid. These ideas were to attenuate any losses created by a mixing and shocking process. Halocarbon refrigerants seem to be a practical and appropriate working fluid for jet cooling system . Compared to the water system, the halocarbon refrigerator can provide higher performance and therefore the required heat source temperature is lower. David Scott, *et al* [9] Supersonic ejectors are utilized in cooling/refrigeration applications since the first 1900s. ejector refrigeration systems are often powered by solar power or by waste heat generated by another process. This paper describes an experimental test bench using R245fa that was assembled and operated at Can met energy in Varennes. The results from this test bench provide a source of reference data which will be wont to validate numerical models of ejectors that would be utilized in refrigeration application Some result the 1D model was found to overpredict the critical condenser pressure of the ejector by between 38% and 69%. Complementary CFD results are significantly better (differences of but 16%), and also allow an in depth view of the fluid flow inside the ejector.

Khalil, M *et al* 10] A mathematical model is developed to style R134a ejector and to predict the performance characteristics of a vapor jet cooling system . These parameters include boiling temperature (65-85°C), condensing temperature (25-40°C), evaporating temperature (0-10 °C), degrees of superheat (0-15°C), nozzle efficiency (0.75-0.95) and diffuser efficiency (0.75-0.95). It is found that the ejector area ratio at boiling temperature of 85°C is about double that at boiling temperature of 65°C for various evaporating and condensing temperatures. The present results confirm that waste heat sources of temperature ranging from 65 to 85°C are adequate to operate vapor jet refrigeration system for air-conditioning applications. Sensitivity of entrainment ratio, COP, ejector efficiency and area ratio of VJRS to boiling temperature increases as evaporating temperature increases. Diffuser efficiency has less effect on performance characteristics of VJRS than nozzle efficiency.

Adriano Milazzo *et al* [11] The Constant Rate of Momentum Change (CRMC) criterion attempts to improve the design of supersonic ejectors that can be used in heat-powered chillers for industrial or air-conditioning use. A prototype chiller using R245fa as working fluid. The analysis is extended to other fluids (water, isobutene, 5 HFCs and three HFOs) whose performance is calculated on a good range of warmth source/sink temperatures. 10 fluids are compared on a wide range of working conditions a water shows a good performance, especially at generator temperatures below 120°C.

Water also features a saturation pressure at generator which is at least one order of magnitude lower in comparison to any other fluid, allowing a lighter and cheaper construction but High COP is also obtained by the low-GWP fluid R1233zd that could be an interesting alternative, though obviously the fluid cost is much higher in comparison with steam.

E.D. Rogdakis *et al* [12] This paper discusses the behavior of ammonia (R-717) through an ejector, operating in an air conditioning system with a low temperature thermal source. For the detailed calculation of employs analytical functions describing the thermodynamic properties of the ammonia. The proposed cycle has been compared with the Carnot cycle performing at an equivalent temperature levels. The influence of three major parameters: generator, condenser, and evaporator temperature, on ejector efficiency and COP. This results of the maximum value of COP was estimated by correlation of the three temperatures for constant superheated temperature (1008°C). The design conditions were generator temperature (76.11-79.578°C), condenser temperature (34- 428°C) and evaporator temperature (4±128°C). A. Selvaraju *et al* [14] When an ejector is operated at choking-mode, it gives a better performance with higher entrainment ratio. To obtain this better performance at different operating conditions, area ratio of the ejector is varied. A computer code based on existing one-dimensional ejector theory is written to analysis performance of the ejector. Comparison of performance of ejector with environment friendly refrigerants, R134a, R152a, R290, R600a and R717 is formed. Among the working fluids selected, R134a gives a far better performance and better critical entrainment ratio as compared with other refrigerants.

Yinhai Zhu *et al* [14] in this paper, a simple yet effective ejector model for a real time control and optimization of an ejector system is proposed. The model is extremely simple, which only requires two or three parameters and measurement of two variables to work out the ejector performance. Compared with existing ejector models, the solution of the proposed model is much easier without coupled equations and iterative computations. Results show that the model is accurate and robust and provides a far better match to the important performances of ejectors over the whole operating range than the prevailing models. This model is predicted to possess wide applications in real time control and optimization of ejector systems.

Zuozhou CHEN *et al* [15] The variable-geometry ejector (VGE) is feasible for unstable heat-source utilization; the ejector can be adjusted to its design point to obtain high efficiency. Moreover, because the adjustable nozzle within the VGE significantly affects the performance of the ejector, a theoretical model is important to guage VGE performance. In this study, a two-dimensional theoretical model was proposed supported an adjustable-nozzle theory. In addition, the suction-flow velocity distribution on the effective area was considered. The performance of the VGE was accurately predicted experimental and calculation result show it is preferable to keep ejector near ideally expanded condition. ejectors are recommended to operate on the turning point for it provides the highest-pressure recovery with a maintained entrainment ratio.

Wang F *et al* [16] An ejector was used in a compression refrigeration cycle for improving its efficiency. A constant pressure mixing model was adopted to simulate the ejector. Whether or not the entrained flow would be choked at the outlet of the suction nozzle and whether a condensation shock would happen at the end of the mixing chamber were both considered. The results indicate that the optimum ejector mixing pressure may be a little less than the entrained fluid's pressure, but far larger than its critical pressure. No condensation shock happens before it flows into the diffuser. The theoretical performances of the hybrid compression cooling system with fixed geometry ejector at off-design conditions are very on the brink of that with the optimum geometry ejector.

III.METHODOLOGY

ANSYS has been used for Analysis of Refrigeration Ejector System by Using Different organic refrigerant" .In which we have used 4 Different refrigerant namely: - R134a, R600a, R717, R154a.After designing the 2d diagram of ejector. Second step is importing the model in Ansys Fluent. After importing the meshing model is done. The type of mesh we used for our model is Tetrahedron meshing. The third step is analysis of model using CFD technique. Computational Fluid Dynamics (CFD) is the simulation of fluids engineering systems using modelling (mathematical physical problem formulation) and numerical methods (discretization methods, solvers, numerical parameters, and grid generations, etc. Firstly, we have a fluid problem. To solve this problem, we should know the physical properties of fluid by using Fluid Mechanics. Then we can use mathematical equations to describe these physical properties. This is Navier-Stokes Equation, and it is the governing equation of CFD. As the Navier-Stokes Equation is analytical, human can understand it and solve them on a piece of paper. But if we want to solve this equation by computer, we must translate it to the discretized form. The translators are numerical discretization methods, such as Finite Difference, Finite Element, Finite Volume methods. Consequently, we also need to divide our whole problem domain into many small parts because our discretization is based on them. Then, we can write programs to solve them. The typical languages are Fortran and C. Normally the programs are run on workstations or supercomputers. At the end, we can get our simulation results. We can compare and analyses the simulation results with experiments and the real problem.

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If the results are not sufficient to solve the problem, we have to repeat the process until find satisfied solution. This is the process of CFD. As our project was confirmed we started the design and analysis the components. Drafting of components using CATIAV5 is done. the types of analysis to be performed to ensure its under various conditions is mentioned below: 1) Fluid Flow (Fluent) We performed impact analysis in ANSYS 20.0, with P-shell method with tetrahedron type element, with 5 mm meshing size. We got **2911** elements with **3511** nodes. The above-mentioned fluent analysis are performed on our Ejector from which we got some results and conclusions, with Pressure & temperature diagrams of ANSYS workbench, which is as follows.

IV. MODELING AND ANALYSIS

While considering the refrigeration compressor, air compressor problem could stem from one of many issues, such as an air leak, an oil leak or a broken part, Excessive noise in operation. In some cases, you might have insufficient pressurization or air flow. To overcome these difficulties, we design "Refrigeration Ejector". To reduce the compressor work in vapour compression cycle and reduce space of the system. The ejector outlet pressure to match compressor outlet pressure and optimize geometry and operating conditions by using CFD technique. The CAD model of Ejector is prepared in Ansys Workbench 2020R2. During modelling, from converging to diverging section it is taken as 576.8mm. Diameter of converging section is of 70mm

Table 1. Dimensions of Ejector Model

Description	Dimension
Inlet diameter of motive nozzle	8.4
Outlet diameter of motive nozzle	21.2
Suction tube diameter	10
Diameter of mixing section	39
Total length of constant area mixing section	90
Inlet diameter of diffuser	39
Outlet diameter of diffuser	76
Length of the diffuser	222.8

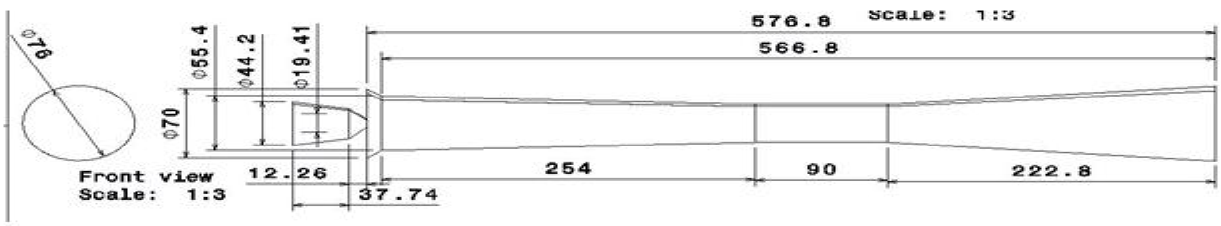

Figure 1: 2d view of Refrigeration Ejector

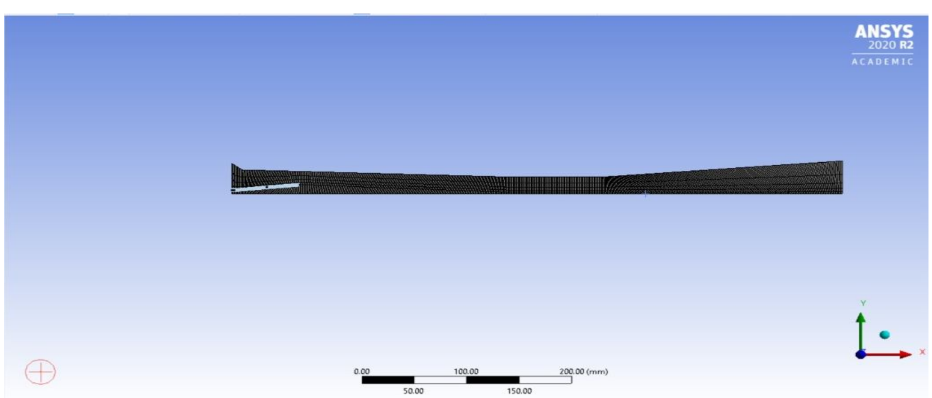

Figure 1: 2d view of Refrigeration Ejector

Model is imported and after that we have applied boundary condition

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V. RESULT AND DISCUSSION

In this paper represent by experimental analysis of refrigeration ejector by using different organic refrigerants like R134a, R152a, R600a, R700.Working fluids were selected based on the criteria of low environmental impact and good performance in the range of operating conditions adequate for using solar thermal energy as primary heat source. Simulation results were obtained with a CFD model using FLUENT (ANSYS).

From above analysis we have come to the result. If Pressure increases, entertainment ratio decreases, and it effects on coefficient of performance. Means if entertainment ratio decreases performance will increase. If we compare all the refrigerant their Coefficient of performance ranges between 70-80%. Entertainment ratio of R717 is lower than other refrigerant so efficiency of R717 is greater than another refrigerant.

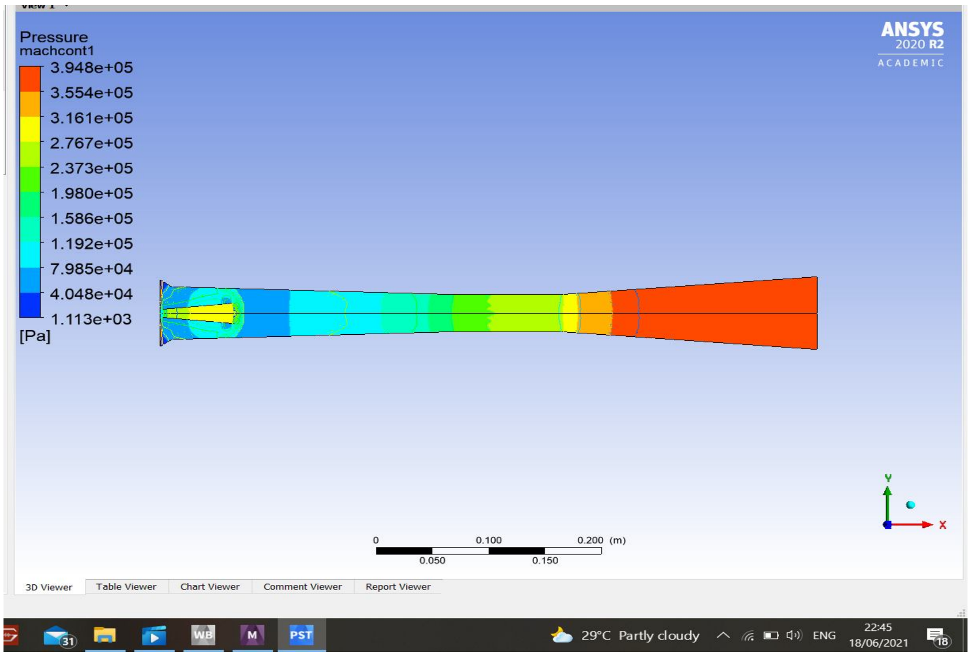

Figure 2: Pressure contour

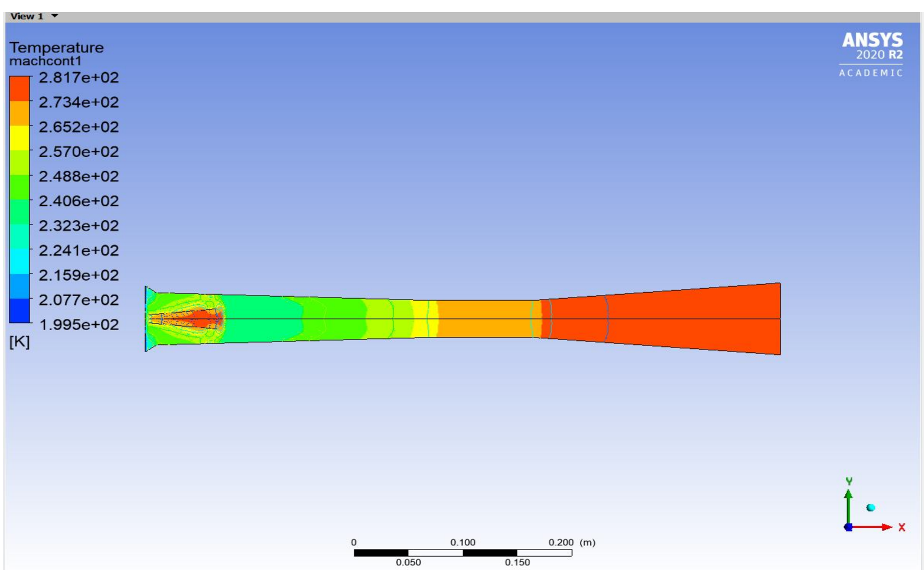

Figure 3: Temperature Contour

Here we have compared Entertainment ratio and Pressure of Generator of various refrigerant

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A. *Refrigerant*

R134a

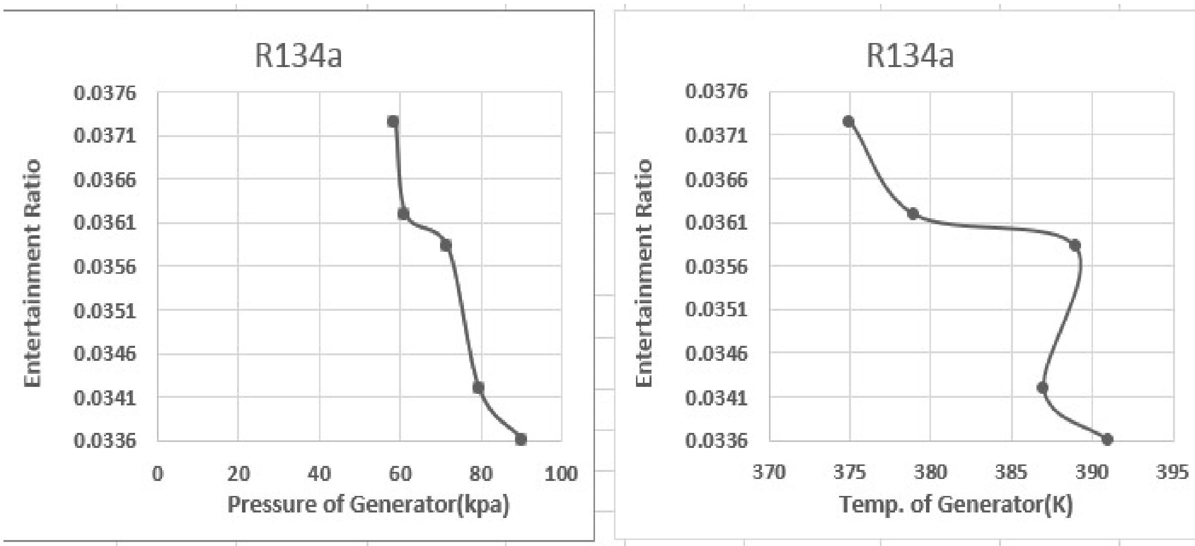
Pg (Kpa)	Tg (k)	Pe (pa)	Te (k)	Pout (bar)	Tout (k)	ENTRAINMENT RATIO
58.7	375	987	283.2	3.948	3.948	0.03724

R152 **a**

Pg (Kpa)	Tg (k)	Pe (pa)	Te (k)	Pout (bar)	Tout (k)	ENTRAINMENT RATIO
58.7	375	987	283.2	3.948	289.8	0.03514

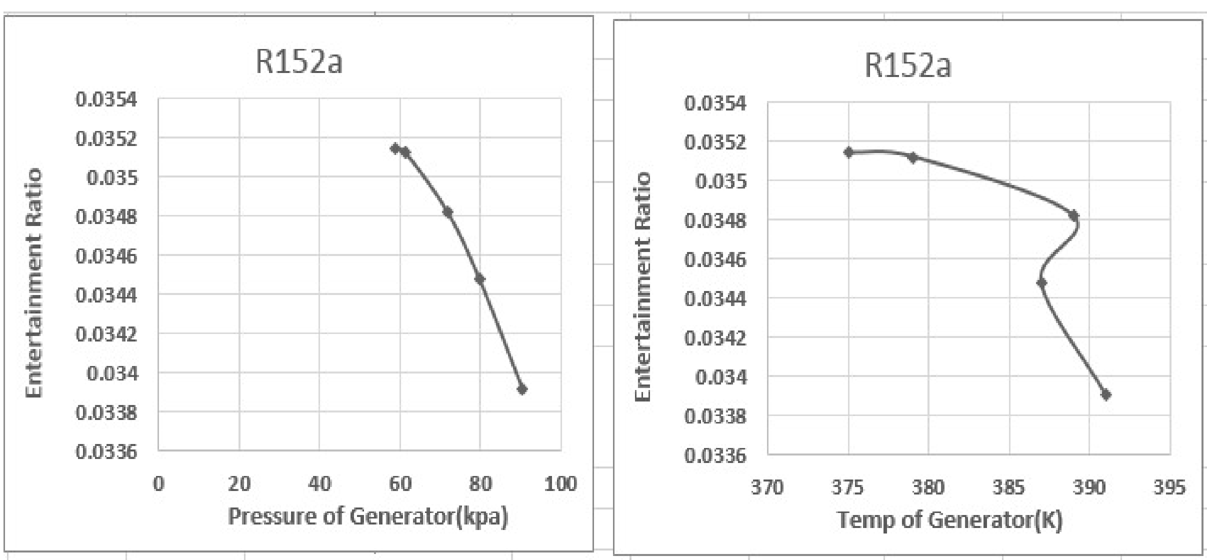
R600a

Pg (Kpa)	Tg (k)	Pe (pa)	Te (k)	Pout (bar)	Tout (k)	ENTRAINMENT RATIO
58.7	375	987	283.2	3.948	289.8	0.03514



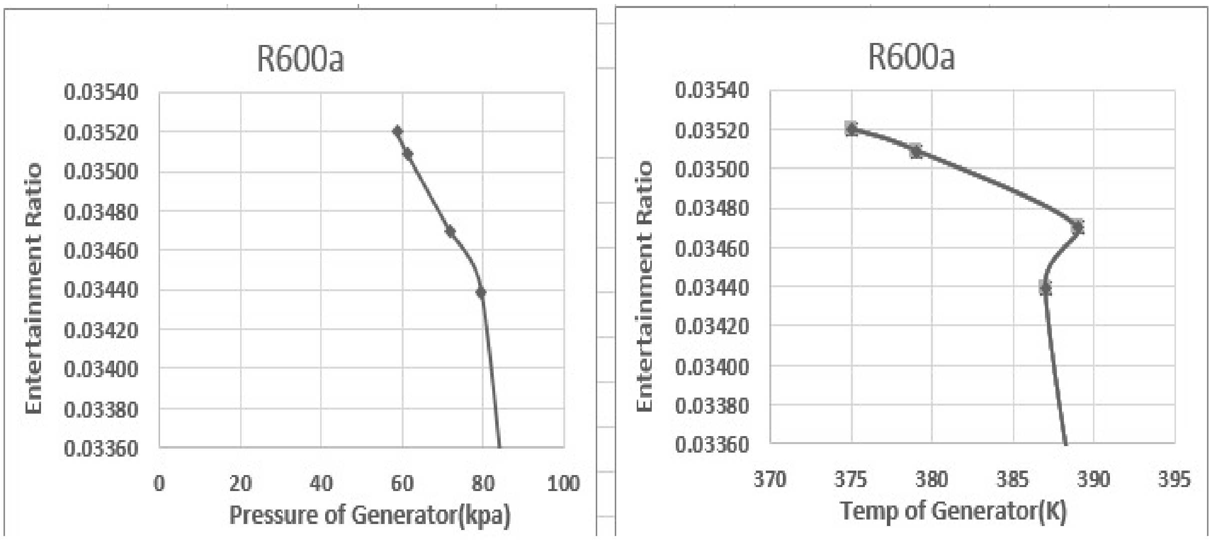
Pg v/s entertainment ratio Tg v/s entertainment ratio

Figure 4:- Comparison chart of Refrigerant R134a



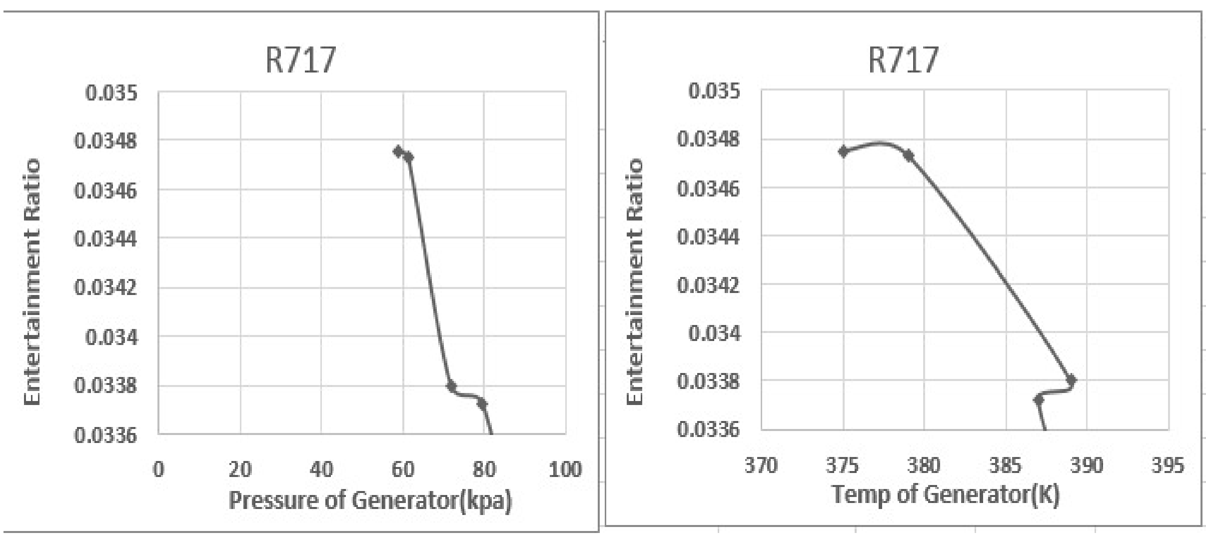
Pg v/s entertainment ratio Tg v/s entertainment ratio

Figure 5:- comparsion chart of Refrigerant R152a



Pg v/s entertainment ratio Tg v/s entertainment ratio

Figure 6:- comparsion chart of Refrigerant R600a



Pg v/s entertainment ratio Tg v/s entertainment ratio

Figure 7:- comparsion chart of Refrigerant R717a

VI. CONCLUSIONS

A. The ejector cycle refrigeration is a green refrigeration technique to improve the performance of the ejector refrigeration system.
B. The understanding of the flow of the fluid in the ejector is very essential. In the present study, the flow of the primary fluid after the exit of the nozzle, subjected to a different pressure is investigated.
C. The effect of the deflection of the primary flow on the secondary flow is determined.
D. CFD simulations was performed to identify optimum geometry and optimum operating conditions.

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