A review on Present development in refrigeration jet ejector system

Mr. Ajeet Bergaley[1] Ajay Kumar Jatav[2]
[1]Assistant Professor [2]Student
[1,2] Department of Mechanical Engineering
[1,2]Institute of Engineering and Technology, davv Indore

Abstract: This paper focuses and gives idea on the development of ejector cooling system, and also focuses ejector governing equations, or some idea gives to rapid increase in energy demand in refrigeration , most of experimental studies have been done in this field ,but some researches still remains for future, like Other parameter such as the length of constant area mixing section and converging angle of constant pressure mixing are less studied because of their small influence of ejector performance.

A. Introduction

Development of cooling system working with thermal energy can avoid a rapid increase of electricity demand. We have studied an ejector refrigeration cycle, which could provide cooling by using solar thermal energy. Because an ejector itself is key component in this cycle to get higher performance by the suction ability, the ejector configuration design is important .analysis of the behavior of refrigerant flow in the ejector is an effective way to get an appropriate ejector configuration. Refrigeration system using an ejector is an interesting system because of its environmentally friendly operating characteristics .low-grade thermal energy can be used to drive this system. An ejector can convert low heat energy obtained from solar energy or rejected heat from many factories or any heating process to useful refrigeration, an ejector system also allows the use of Water. Which is the most environmentally friendly substance As a working fluid in the system researchers are still trying to improve the ejector cooling system, investigating the effect of operating conditions. Developments of industry and increase in population and higher living standards have caused a great demand of energy, and consequently energy shortage and higher prices as well as global environmental problems. this forces researcher to turn to renewable energy alternatives and raises voices for seeking approaches of utilizing low- grade energies. in the refrigeration field, the ejector refrigeration system provide a promising way of producing cooling effect by harvesting waste heat from industrial process or using renewable energy, such as solar radiation and geothermal energy. Which makes such systems particularly attractive in this energy conscious –era. They have some other remarkable merits, such as no moving parts which make them vibration free, having low initial and running cost with long lifetime, and providing the possibility of using environmentally friendly refrigerants. The has also been incorporated in to other systems like vapor absorption system and vapor compression systems. In order to achieve better system performance and higher energy efficiency, however the ejector refrigeration system have relatively low efficiency and difficulty in their design, which greatly limit their widespread in commercial sector .and consequently a number of researches have been done to understand their working characteristics and to improve their performance and use.

B. General working process of ejector

An ejector is a flow device that allows a high pressure primary fluid to accelerate and induce a low pressure secondary fluid in to the primary fluid path. As the two fluids mix through a diffuser section, a pressure recovery occurs, which enables and the ejector to fulfill the function of a compressor or a pump. The term secondary means the driven, passive or enlarzed flow. And the term primary means driving, motive or enlarging flow, the ejector has a simple structure of four parts, a nozzle, a suction chamber, a mixing chamber, a diffuser. Show in fig,(1) pressure and velocity variation along the ejector ,refers from(jianyong chen ,sep/2015 review of ejector application)

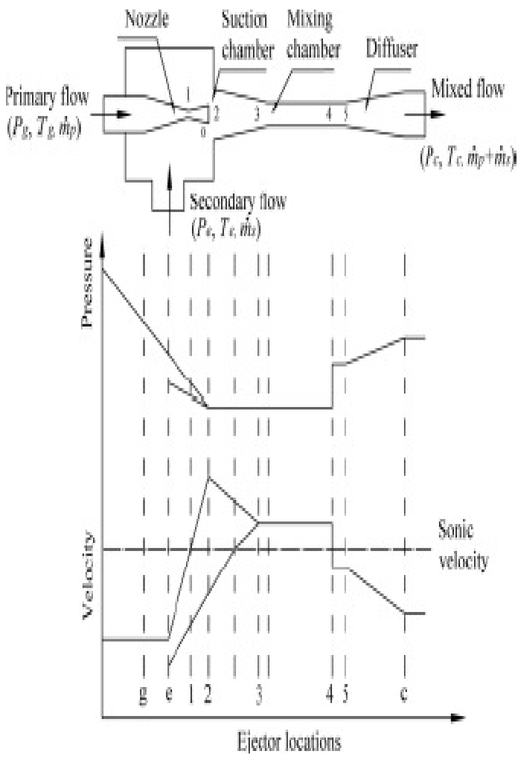

Fig.1 Schematic diag. Of ejector and variation of pressure/ velocity along the ejector

C. Ejector performance evaluation

The most important parameters for assessing ejector performance are the entrainment ratio(μ)defined as the ratio of mass flow rate of secondary fluid (Ms) to that of the primary flow(Mp).

$$\mu = \frac{M_s}{M_p} \quad \text{(a)}$$

Table (1), Experiment result of ejector refrigeration system under various condition

Ref.	C.C	W.F	Evo Tem °C	Cond Tem °C	Gen Tem °C	cop
Chunnanond & Aphomratana [6]	3	WATER	5:15	22:36	110:150	0.28:0.48
Selvaraju&mani [7]	0.5	R134a	2:13	26:38	65:90	0.03:0.16
Sankarlal And Mani [32]	2	R717	5:15	30:36	62:72	0.12:0.29
Chaiwongsa and Wongwise [33]	2.5	R134a	8:16	26.5:38.5	50:60	0.3:0.48
Yapic Et.al [34]	2	R123	0:14	108 kap:142 kpa	83:103	0.12:0.39

\W.F=working fluid, C.C=cooling capacity COP=coefficient of performance

E. Governing equation of ejector design

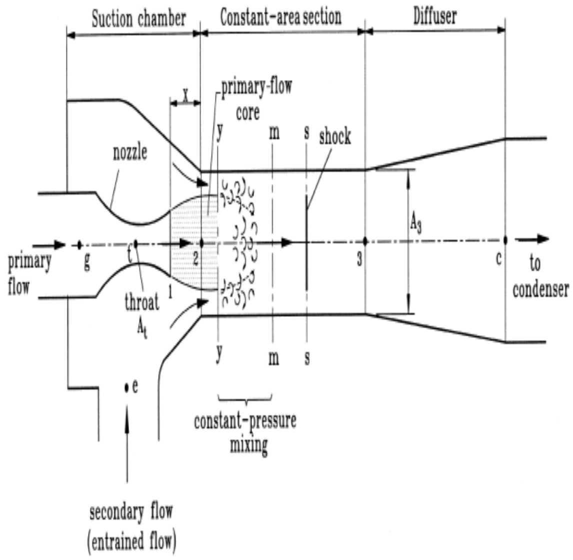

Fig.2 schematic diag. of ejector performance

1. Primary nozzle

For a given inlet stagnant pressure *Pg* and temperature *Tg*, the mass flow through the nozzle at choking condition follows the gas dynamic equation where hp is a coefficient relating to the isentropic efficiency of the compressible flow in the nozzle. The gas dynamic relations between the Mach number at the exit of nozzle

*M*p1 and the exit cross section area *A*p1 and pressure *P*p1 are, using isentropic relations

$$m_p = \frac{p_g A_t}{\sqrt{T_g}} \times \sqrt{\frac{\gamma}{R}\left(\frac{2}{\gamma+1}\right)^{(\gamma+1)/(\gamma-1)}}\sqrt{\eta_p} \qquad (1)$$

2. Entrained mixed flow mi to exit section y-y

the entrained flow reaches choking condition at the *y*–*y* section, i.e. *M*sy . 1. For a given inlet stagnant pressure *P*e, we have

$$m_s = \frac{p_e \times A_{sy}}{\sqrt{T_e}} \times \sqrt{\frac{\gamma}{R}\left(\frac{2}{\gamma+1}\right)^{(\gamma+1)/(\gamma-1)}}\sqrt{\eta_s} \qquad (2)$$

3. Mixed flow at section m-m to section 3-3

Two streams starts to mix from section *y*–*y*. A shock then takes place with a sharp pressure rise at section *s*–*s*. A momentum balance relation thus can be derived as where *V*m is the velocity of the mixed flow and fm is the coefficient accounting for the frictional loss

$$\varphi_m[m_p V_{py} + m_s V_{sy}] = (m_p + m_s)V_m \qquad (3)$$

$$m_p\left(C_p T_{py} + \frac{V_{py}^2}{2}\right) + m_s\left(C_p T_{sy} + \frac{V_{sy}^2}{2}\right) = (m_p + m_s)\left(C_p T_m + \frac{V_m^2}{2}\right) \qquad (4)$$

5 .Match no. of mixed flow

Match no. for mixed flow can be evaluated.

$$M_m = \frac{V_M}{a_m} \qquad (5)$$

Where,

$$a_m = \sqrt{\gamma R T_m} \qquad (6)$$

6 Temperature and match no.

$$\frac{T_e}{T_{sy}} = 1 + \frac{\gamma-1}{2}M_{sy}^2 \qquad (7)$$

F. System working process

Shows the conventional ejector refrigeration system(CERS) with two ejector models which are extensively used in refrigeration technology .the working process of the system is generalized as low grade energy Tg is delivered to the generator for vaporization ,the high pressure vapor from the generator i.e. the primary flow, enters into the nozzle and draws low pressure vapor from the evaporator i.e. secondary fluid. The two flows undergo mixing and pressure recovery in the ejector ,the mixed flow fed into condenser .where it considerably rejecting heat in to environment(Qc)the liquid from condenser divided into two parts. one parts goes through expansion device and then enter into evaporator to produce refrigeration effect (Qe) the rest liquid is pumped back to generator via the circulation pump and complete a cycle. show in fig (3),referred from(Jing Yong chen, SEP,/2015)

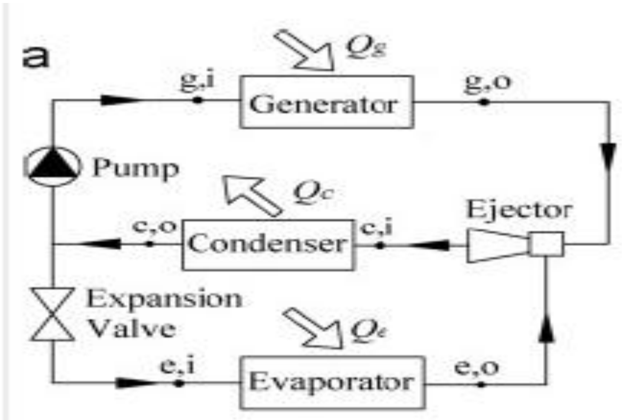

Fig.3 schematic dig, of CER system with ejector

Evaluate system performance by mathematical simulation method, it is quick and simple. Term coefficient of performance (COP) is defined as refrigeration effect to that of work in put,

$$COP = \frac{Q_e}{Q_g + W_{pump}} \qquad (b)$$

G. Literature review

The ejector was introduced as an engineering device in the early 20th century .at the same time, researcher started to investigate its working mechanism. In a paper published in 1950,keenam and Neumann[3] presented the first comprehensive theoretical and experimental analysis of the ejector problem .the throat area at the primary nozzle has been the most commonly researched parameter in matter by introducing needle valve inside the nozzle the effective throat area varies according with the axial position of the needle. [1] Presented the first comprehensive theoretical and experimental study on ejector. Their results have the distinction of being used as the basis for ejector design and analysis in almost all the subsequent researches two established technique are used for modeling ejector the constant pressure model and the constant area model. Sun and Eames research contemporary operation is limited and coefficient of performance (COP) is very low widely. Popular

[2] varga et al. worked on a similar design validating it through CFD ,their simulations predicted the mass flow of the motive fluid with an average relative error of 7.7% along the entire range of needle positions in comparison with the measures obtained on their test stand ,provide that CFD is an effective tool of validate variable geometry design

[3]varga at el 2012, made a CFD analysis of the same variable geometry ejector with R152a and R600a as refrigerants design for a 1 KW cooling capacity .the resulting COP was found to be 177% higher than the one of the fixed geometry ejector at low condenser pressures

[4] satha Aphornratana and Ian w.eames 1997,describes an experimental study of a steam ejector refrigeration using an ejector with a primary nozzle that could be moved axially within the mixing chamber ,the test showed that a single optimum primary nozzle position cannot be define to meet all operating conditions. Each operating condition require a particular optimum nozzle position .the COP and cooling capacity can be varied as much as 100% by changing the nozzle position moving the nozzle in to the mixing chamber caused COP and cooling capacity to decreases when temperature was maintained constant.

[5] M.dennis ,k 2010,in this paper uses software modeling to examine the use of variable geometry ejectors and cold stores to increase annual yield of an ejector the study concludes that a variable geometry ejector is able to increase yield by 8-13 % compared to fixed geometry ejector however 46-50% increase in solar friction in 60MJ cold storage is included compare to fixed geometry ejector.

[6] Paul R.Pereira 2014 studied two geometrical factors. the area ratio and the nozzle exit position . can be actively controlled .the control of area ratio is achieved by a movable spindle installed in the primary nozzle. the influence spindle position (SP) and condenser pressure on ejector on ejector performance are studied. the very good ejector performance were studied when generator and evaporator temperature are 83°Cand 9°C respectively, COP varied between 0.4 and 0.8 depending on operating conditions.

[7] Alejandro Gutierrez, Noel Leon 2014, studied an ejector that implements variable geometry mechanisms is proposed and evaluated using CFD simulations. Change to design current ejector are also discussed. Investigating the feasibility of the multiple outlet design showed that by having several orifices at the primary nozzle exit wall. Thus increased entrainment ratio of the ejector by mixing of primary and secondary fluids. An improvement of 8.23% over the base line ejector entrainment ratio was analyzed with CFD

H.CONCLUSION

Studies on variable geometry ejector refrigeration systems involve system modeling, design, and refrigeration selection. The optimal geometry parameters of ejector depend on working fluid and operating conditions. Other parameter such as the length of constant area mixing section and converging angle of constant pressure mixing are less studied because of their small influence of ejector performance.

1. at any given condenser, evaporator and generator temperatures. Only one unique geometry will result in highest COP.
2. At any given temperatures of evaporator, generator and condenser variable geometry ejector have highest COP and less solar plate area as compare to fixed geometry ejector.
3. Ejector refrigeration are mechanically simple and have low investment cost. However such refrigerators have relatively low COP. Than other conventional refrigeration technology.
4. The optimum value of the primary nozzle diameter decreases with increasing generator.
5. The optimum primary nozzle position or converging angle cannot be predefined to meet all operating condition. Whereas the operating conditions are different from the design point.

Through a large amount of work have been conducted on ejector geometries, further efforts are still needed

1. To make a comprehensive study about the effect of operating conditions, ejector geometry and working fluid characteristics

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