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A Review on dimension of ejector

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Abstract-*Ejectors are widely used in the refrigeration system and the evaluation of the ejector performance is important to find dimensions of ejector. In this paper, a research reviw on ejector is studied. The research show that the dimensions has a strongly affect to predict the ejector entrainment ratio, COP, cooling effect and performance of ejector. Furthermore, the dimension is more accuracy and has properly found by mathemetical modeling, research articles and software analysis. It is hoped that the proposed research is useful for finding the dimension of ejector.*

Keywords*- Ejector; COP; Dimensions,*

I. INTRODUCTION

Application of ejector is mostly in the refrigeration system, fuel cell system, vacuum system and desalination plant. Ejector give system simple structure, low maintenance cost and long service life and compact design. Recently researcher is more focused to use the low grade thermal energy such as solar energy for producing refrigeration effect [4]. However system ejector refrigeration system has lower efficiency, low C.O.P. and complex thermodynamic behavior compare to vapor compression refrigeration. Furthermore, The optimum working conditions for the refrigeration is difficult to achieve for the ejector refrigeration system.

A number of literatures were published on the ejector refrigeration system since 19^{th} century. However, The drawbacks of ejector refrigeration system are Low COP of ejector refrigeration system is relatively compared with adsorption, absorption and convectional VCR system and fluid pump must be deliver working fluids at high pressures from condenser exit to feed the vapor generator.

II. EJECTOR REFRIGERATION SYSTEM

An ejector is made from four parts, nozzle section, suction chamber, mixing section and diffuser. The vapor flow becomes supersonic after throat at a condition of a back pressure of the diffuser, a generating pressure and a nozzle inlet pressure. The parameters that is used for calculation are a condensing pressure, a mixing section area ratio and a nozzle exit ratio. For design point of view The diameters of the nozzle throat and a mixing section are important for ejector design point of view [3].

The ejector has no moving part device, non mechanical compressor, requiring no maintenance and no lubrication. Main concentration for use of supersonic ejector is maximizing the performance of the refrigeration cycle through thermal compression. The basic components are shown in figure 1 [2].

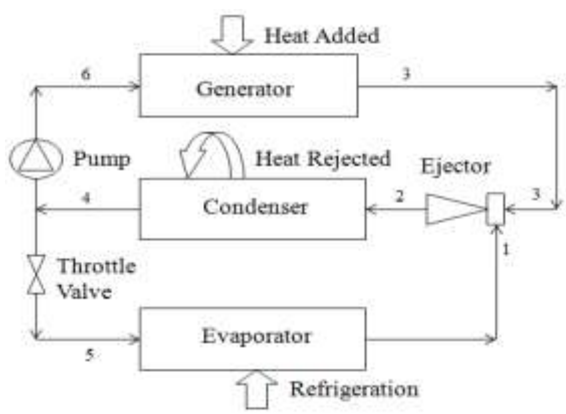


Fig 1 Ejector Refrigeration System

The primary fluid flows the nozzle where pressure is reduced and its velocity increased as shown in figure 2. A zero velocity (Stagnation condition) is considered for the primary fluid inlet in the ejector. At 't' nozzle throat the primary fluid flow reaches sonic velocity. Its Mach number is equal to one. So at the throat of the nozzle primary fluid flow is chocked. Maximum value of mass flux for inlet pressure and temperature is achieved.

The velocity of secondary fluid is increased from inlet of secondary fluid to section y-y. Its pressure is decreased. For mixing of primary fluid and secondary fluid the critical pressure of the secondary fluid is achieved at the beginning of the mixing. So secondary fluid velocity require reaching the speed of sound at design pressure level. Momentum loss of mixed fluid is realized due to the friction between wall surface and mixed fluid through the constant area section. At the end of mixing chamber normal shock is assumed. It may be negligible because the zone of this phenomenon is very thin. After mixed fluid passed the through diffuser its pressure become condenser pressure [1].

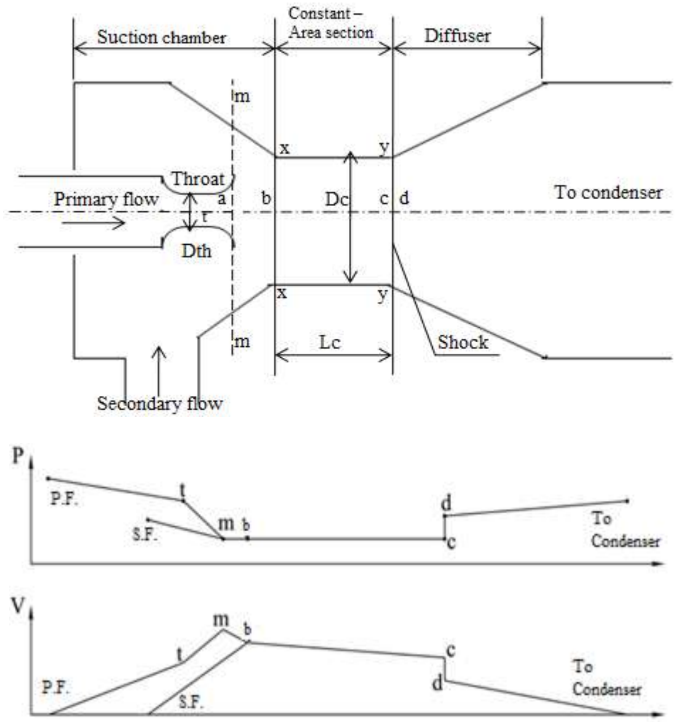


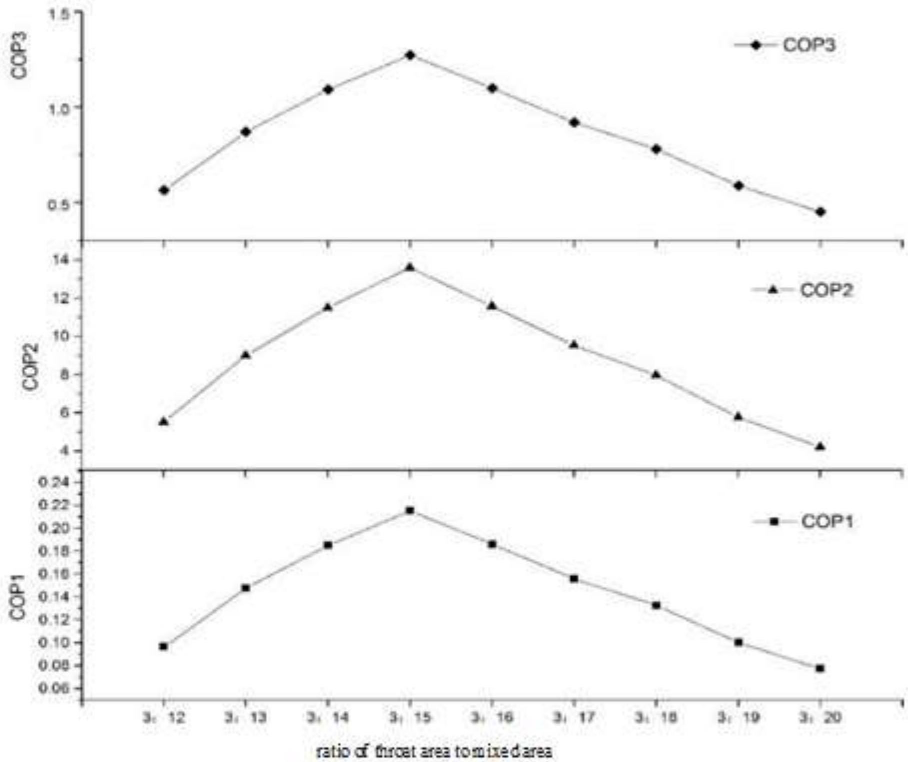
Fig-2 Section of ejector and Pressure-Velocity profiles of ejector

The some assumptions are considered for study of ejector refrigeration system. Heat transfer and friction loss is neglected between the ejector wall and fluid stream. The conditions in the ejector refrigeration system are steady state. The primary and secondary fluids follow ideal gas law and are perfect gases. In the constant area section fully mixed conditions are considered. The mixed flow is always subsonic at the diffuser inlet. The dimensions of the ejector are calculated for the ejector refrigeration system for known entrainment ratio, known inlet condition of primary fluid flow, known inlet condition of secondary fluid flow, known outlet condition of mixed fluid from ejector. The values of the efficiency for the primary and secondary expansion in the suction chamber are known. The value of efficiency of compression in the diffuser is known. The result about the length to diameter ratio for constant area section by Keenan et al is considered for the length to diameter ratio for constant area. The pressure of primary fluid flow and secondary fluid flow at cross-section m is the same. So no shocks due to overexpansion or under expansion of the primary fluid flow. The exit of the primary fluid from nozzle is supersonic. The mixing of the primary fluid and secondary fluid at constant pressure is complete at cross-section x-x. The fluid flow through the ejector is one-dimensional, adiabatic and steady state flow [2].

III. RESEARCH REVIEW

1. The Influence of Ejector's Structure Parameters on the Performance of Ejector Refrigeration System

This research is published by Wenju Hua, Meng-yuan Wanga, Jin-zhe Niea, Yan Gaob, Qun-li Zhangb in Procedia Engineering 205 (2017) 2683–2690 Coefficient of performance (COP) of ejector refrigeration system indicates that the refrigerating capacity can be obtained by consuming unit heat energy. [5] Mechanical work of ejector refrigeration system is only the working medium pump work. Define three kinds of COP to reflect the quantity and quality of energy transfer and conversion process.



$$COP1 = \frac{Q_e}{Q_g + W_p} = \frac{Q_e}{Q_a}, \quad COP2 = \frac{Q_e}{W_p}, \quad COP3 = \frac{Q_e}{W_p + W_g}$$

Figure 4 COP vs ratio of throat area to mixed area

Where COP1 is the ratio of refrigerating capacity to total input energy.COP2 is the ratio of refrigerating capacity to pump power.COP3 is the ratio of refrigerating capacity to total input work, which reflects the relationship between the refrigerating capacity and the working medium pump power and the heat energy of generator [5].

The COP1, COP2, COP3 change trend with the throat area and mixed area ratio drops. The results obviously show that COP1, COP2, COP3 all reach the peak value at the ratio of 3:15. With the ratio changes from 3:12 to 3:15, COP1 increases from 0.1 to 0.22, COP2 increases from 5.5 to 13.6, and COP3 increases from 0.56 to 1.27. Then COP1 declines to 0.08, COP2 declines to 4.2 and COP3 declines to 0.45 when the ratio continues dropping to 3:20. The throat area and mixed area ratio strongly affects the performance of ejector and operating performance of refrigeration system. Under this condition, the optimum ratio of throat area and mixed area is 3:15 [5].

2. Conceptual development and CFD evaluation of a high efficiency – variable geometry ejector for use in refrigeration applications

Alejandro Gutiérrez is published about CFD evaluation in Energy Procedia 57 (2014) 2544 – 2553.The design of the baseline ejector used on the CFD analysis was modeled according to the considerations made by Rusly et al. for R141b as refrigerant; the entire ejector can be described using only three parameters: primary nozzle throat radius (rt), primary nozzle exit radius (rp) and constant area section radius (rc) [6]. The optimum distance between the primary nozzle exit and the constant area section inlet is 5 times the constant area section diameter.. However The nozzle exit and constant area section distance to 1.5 times the constant area section diameter, so this was also used on the study for consistency [9].

The diffuser length is 8 times the constant area section diameter with a divergent angle of 3.5° as the optimum. The primary nozzle inlet and outlet angles as 12° and 7° respectively and 10° for the mixing chamber inlet angle (this one was later increased to 30° with improved results). The optimum is √7.6 times the primary nozzle throat diameter [9].

For consistency the primary nozzle length was also set at 5 times the constant area section diameter. The throat and the constant area section diameter were taken from the AG ejector. The figure 5 resumes the design rules used on the base ejector [6].

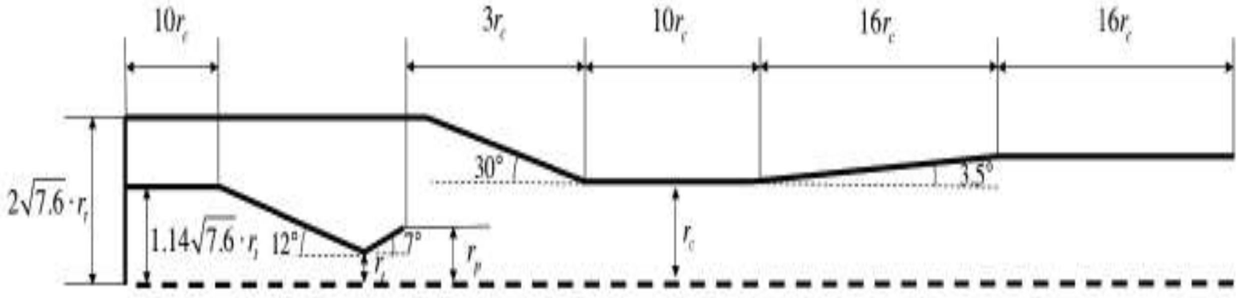


Figure 5 of Axisymmetric view of the ejector showing the employed design rules

The axisymmetric model was meshed with a maximum element face size of 0.25 mm, using a quad-dominant structured mesh with a total of 35,282 elements. A second order pressure based solver with the realizable k-ε turbulent model was chosen in accordance with the CFD work done [6]. The boundary conditions for both the primary and the secondary inlets were designated as pressure inlets, corresponding to the saturation pressure of the R141b at the generator and evaporator desired temperatures, while the outlet was set as a pressure outlet with the saturation pressure at the condenser temperature [6].

3. Ejector Configuration for designing a Simple and High Performance Solar Cooling System
4.

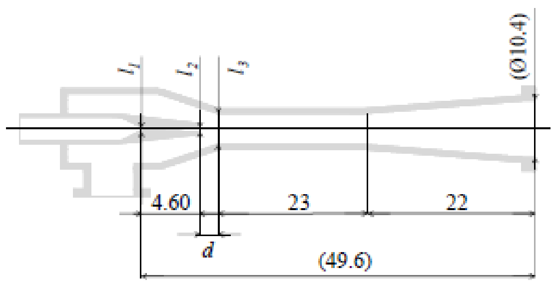


Figure 6 of Configuration of ejectors A and B

Figure 6 and Table 1 show two sets of the configuration of ejectors A and B. The ejector A was designed by Chan et al. in our group [7], which has a mixing-section diameter of 2.36 mm and the performance was about 0.35 for ω with T_c of about 27°C at a condition of T_e = 15 °C and T_g = 60 °C as reported . The COP_T of ejector A is about 0.4, which is a linear function of ω as explained above. The ejector B, which has a mixing-section diameter of 3.00 mm, was designed based on the result of numerical analysis [7].

Table 1 Configuration parameters of ejectors A and B

	Nozzle throat diameter l_1	Nozzle exit diameter l_2	Mixing Section diameter l_3
Ejector A	1.40 mm	2.20 mm (A_{NE} = 2.45)	2.36 mm (A_{MIX} = 2.84)
Ejector B	1.40 mm	2.20 mm (A_{NE} = 2.45)	3.00 mm (A_{MIX} = 4.55)

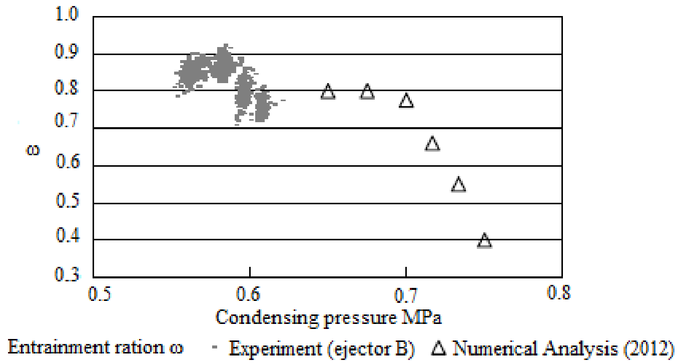


Figure 7 Comparison of experimental and numerical analysis results for ω vs. condensing pressure Pc for ejector B at Te = 15 °C, Tg = 60 °C

The COP $_T$ of ejector B was about 0.85, which reached as double as that of ejector A. On the other hand, as shown in figure 7, The comparison of experimental and numerical analysis for ejector B at the same condition of T_e = 15 °C and T_g = 60 °C, The ω of the experiment is slightly higher than the numerical analysis result, but the critical pressure is lower by approximately 0.1 MPa than that of the numerical analysis result [7].

5. Experimental investigation of performance of vapor ejector refrigeration system using refrigerant R123

The important dimensions of the mixing chamber and nozzle are given in Figure 8 a and b, respectively. As indicated in the figures, the nozzle and mixing chamber throat diameters are 2.85 mm and 9.0 mm, respectively. According to these values, the ejector area ratio is 9.97 [8].

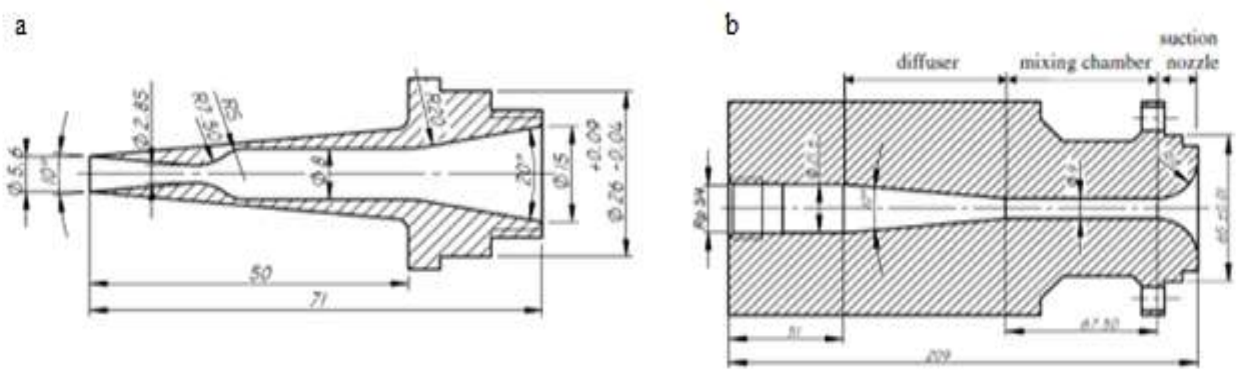


Figure 8 Elements of the ejector (a) supersonic nozzle and (b) mixing chamber with diffuser

In the present study, the performance of the ejector refrigeration system was determined using a novel ejector by testing the system at operating conditions that are optimum for the ejector area ratio Ar = 9.97 and R123 refrigerant. A COP of 0.39 was obtained from the modified system at Te = 10^{o}C, Tg = 98^{o}C and P_ c ¼ 129 kPa. from the present study, it was seen that the performance of such a refrigeration system could be improved if its ejector was designed carefully and manufactured by using good manufacturing technique. When the condenser and evaporator temperatures are selected according to practical considerations, if maximum cooling capacity is desired to be obtained efficiently from the system, it should be operated at the optimum generator temperature and the nozzle position corresponding to the ejector area ratio [8].

IV. CONCLUSIONS

I concluded that dimension of ejector is most impotent parameter for effective performance of ejector refrigeration system. The dimensions of ejector are selected near to the above ejector dimensions for better performance. The optimum area ratio of ejector is 9.97 for refrigerant R 123. A smaller nozzle exit area can avoid the energy loss of shockwave that makes reliable repeatability. The primary nozzle length is also set at 5 times the constant area section diameter. The COP cooling capacity, injection coefficient and heat requirement reach the peak value at the optimal ratio value.

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