S. Gurulingam, A. Kalaisselvane, N. Alagumurthy / International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com
Vol. 2, Issue 6, November- December 2012, pp.1650-1653

Numerical Study of Performance Improvement of Jet Ejector

S. Gurulingam[a*], A. Kalaisselvane[b], N. Alagumurthy[c]

[a]Research scholar, Department of Mechanical Engineering, Pondicherry Engineering College, Pondicherry, INDIA

[b]Assistant Professor, Department of Mechanical Engineering, Pondicherry Engineering College, Pondicherry, INDIA

[c]Professor, Department of Mechanical Engineering, Pondicherry Engineering College, Pondicherry, INDIA

Abstract

In this paper, numerical performance analysis of jet ejector's has been carried out using irreversibility characteristics. The various losses that occur in different regions of jet ejector have been quantified and an attempt has been made to increase the efficiency of jet ejector by reducing the losses based on minimization of entropy method. In the present work, new technique has been identified to minimise the momentum difference between the motive and the propelled fluid. This was carried out by forcing the propelled stream using a blower. The geometrical design parameters were obtained by solving the set of governing equations, a CFD package; FLUENT and it has been effectively used to evaluate the optimum entrainment ratio for a given set of operating conditions.

Keywords: Jet ejector, Efficiency, Irreversibility, CRMC, Forced draught

1. Introduction

The jet ejector essentially consists of nozzle, converging section, mixing throat and diffuser. According to the Bernoulli's principle when fluid is pumped through the nozzle of a jet ejector at a high velocity, a low pressure region is created before the outside of the nozzle. A second fluid gets entrained into the jet compressor through this low pressure region. The dispersion of the entrained fluid in the throat of the ejector with the fluid jet emerging from the nozzle leads to intimate mixing of the two phases [1]. A diffuser section of the mixing throat helps to recover the pressure. The fluid jet performs two functions: 1. It develops the suction for the entrainment of the secondary fluid. 2. It provides energy for the dispersion of the one phase into the other. This process has been largely exploits in vacuum systems in which high speed fluid stream is used to generate vacuum. In the ejector, three main irreversibility's are "pure mixing" "kinetic energy losses," and normal shock wave. The "pure mixing" and "kinetic energy losses" occur simultaneously in the mixing section followed by the normal shock wave. Irreversibility due to mixing can be eliminated by appropriate choice of gas. In this aspect, Arbel et al. (2003) [1] analysed and characterized theirreversibility's (pure mixing, kinetic energy, and normal shock wave) of the ejector internal processes to improve the overall efficiency. Eames (2002) [2] introduced the concept of constant rate momentum change (CRMC) method to eliminate the loss due to shock wave for supersonic-jet pumps. Somsakwatanawanavet (2005) [3] optimised the design parameters (optimum length, throat diameter, nozzle position, and inlet curvature of the converging section) for high efficiency jet ejector. In the literature review, most of the researchers have concentrated to introduce the new methodology to improve the performance of the jet ejectors. In this regard, an attempt has been carried out to introduce the forced draught concept (blower) at the secondary inlet of the jet ejector to improve the performance by reducing the momentum difference between the two streams. This decrease the kinetic energy loss in the mixing area by forced draught system.

2. Description of the Model

In the present model, blower is used to increase the velocity of the secondary stream at the inlet. This reduces the momentum difference during mixing and in turn reduces the kinetic energy losses. The schematic view of the present model is shown in Fig.1.

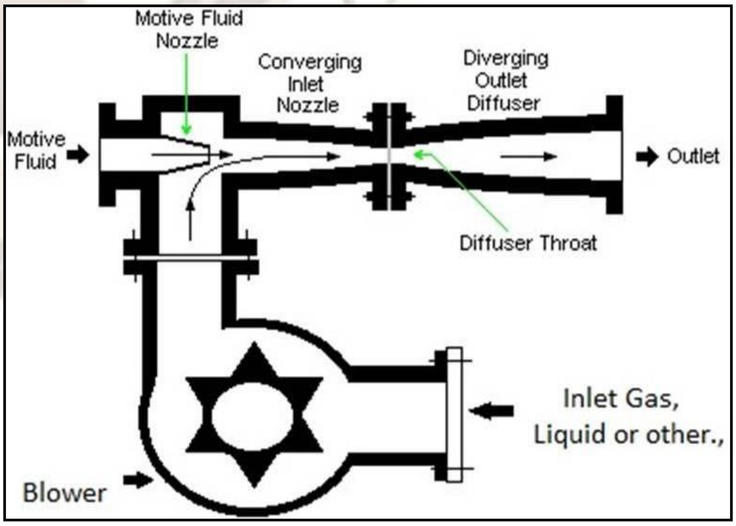


Figure 1. Description of the model

Based on the present model, an efficiency comparison is made to compare the small and large momentum differences between the motive and propelled streams. The mass flow rate and velocity of the primary and secondary fluid are 1kg/s, 10 m/s and 1kg/s, 1 m/s respectively. The efficiency of the jet ejector is found to be 54.5%. If the velocity of the secondary fluid is increased to 6 m/s, then the efficiency of the jet ejector is 94.1%. The efficiency is calculated based on Eq. (1).

$$\eta = \frac{E_{kmix}}{E_{km} + E_{kp}} \quad (1)$$

Where

η = efficiency

E_{kmix} = Kinetic energy of mixed stream J/s

E_{km} = Kinetic energy of motive stream J/s

E_{kp} = Kinetic energy of propelled stream J/s

The calculation shows that the efficiency increases substantially when the momentum difference between the motive and propelled streams decreases. This is achieved by increasing the velocity of the propelled fluid using a blower, keeping the mass flow as constant.

3. Numerical Study

A 2D model of the jet ejector is created in Gambit. Axi- symmetric solver is chosen in the FLUENT, 3D effects can be reflected by 2D jet ejector model. The geometrical design parameters of the jet ejector were obtained by solving the steady state Navier-Stokes equations as well as the equation of mass and energy transport for compressible flows, which is given in Eq. 2-4. Turbulent k-ε model was used to solve the equations using CFD package, FLUENT. Grid independent study was carried out. The optimum structured quadrilateral grid size of 0.25 mm was used in the present model. The meshed geometry for conventional and CRMC based jet ejector are shown in Fig. 2. The following boundary conditions are used in the present model. The boundary conditions are (1) Mass flow inlet at nozzle inlet, (2) Pressure inlet at secondary flow inlet and (3) Pressure outlet at exit of the jet ejector. Theconverged solutionswere obtained for the residual values of 10^{-6}, 10^{-3}, 10^{-6}, 10^{-3}, and 10^{-3} for continuity, momentum, energy, k and epsilon.

$$\partial/\partial xi\ (\rho ui) = 0 \quad (2)$$

$$\partial/\partial xi\ (\rho uiuj) = \rho gi - \partial P/\partial xj + \partial/\partial xi\ (\tau ij - \rho u,iu,j) \quad (3)$$

$$\partial/\partial xi\ (\rho CpuiT) = \partial/\partial xi\ (\lambda\ \partial T/\partial xi - \rho Cpui,T,) + \mu\Phi \quad (4)$$

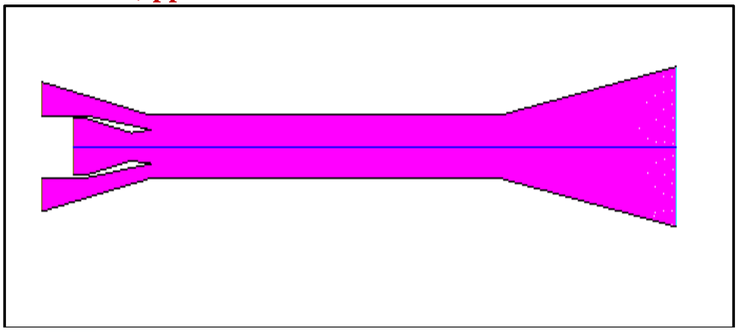
Where

τij is the symmetric stress tensor,

$\rho u,iu,j$ is the Reynolds stress,

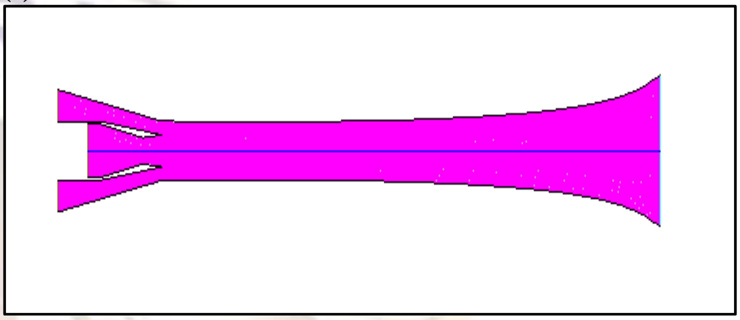
$\rho Cpui,T,$ is the turbulent heat flux and

$\mu\Phi$ is the viscous dissipation.



(a) Conventional

(b)



(c) CRMC based method

Figure.2 Meshed geometry for conventional and CRMC jet ejectors.

4. Results and Discussion

The simulated results have helped in understanding the local interactions between the two fluids, and recompression rate which in turn made it possible for a more reliable and accurate geometric design and operating conditions. Many numerical studies about supersonic ejectors have been reported since 1990s in predicting ejector performance and providing a better understanding of the flow and mixing processes within the ejector (Riffat et al [4], Ouzzane&Aidoun [5], Alexis &Rogdakis [6], Chunnanond&Aphornratana [7]), pump (Beithou&Aybar [8]) and in mixing processes (Arbel et al [9]).

The jet ejectors are designed for ER =1. Fluent simulation shows that the jet ejector designed based on conventional method produces an ER = 0.774, whereas CRMC based jet ejector produces an ER = 0.85. In conventional jet ejector there is drop in ER since shock wave occurs at the end of constant area mixing chamber. Fig 3 shows the static pressure along the axis of the jet ejector. The presence of shock wave increases the static pressure. Since shock wave generation is an irreversible process, there is drop in efficiency of jet ejector.

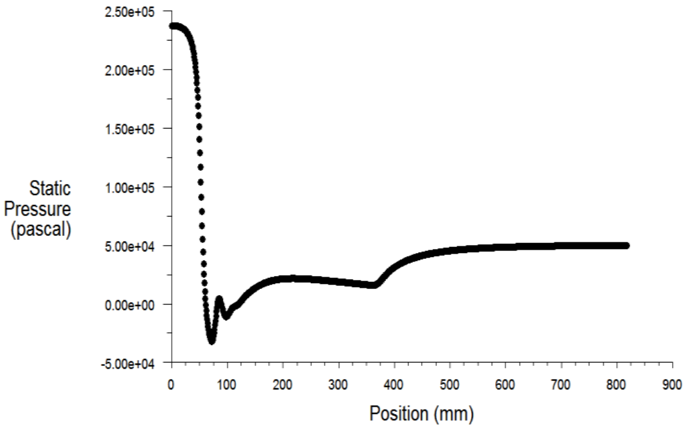


Figure 3. Static pressure along the axis of conventional jet ejector.

CRMC method eliminates the formation of shock wave in the mixing area. The cross sectional area of the mixing region of jet ejector is not constant. The mixing region and diffuser are replaced by a convergent and divergent diffuser. The momentum of primary fluid is transferred at constant rate to secondary fluid by varying the cross section of the pipe. Fig (4) shows the static pressure along the axis of the jet ejector. The raise in the static pressure (pressure recovery from kinetic energy after mixing) occurs at constant rate.

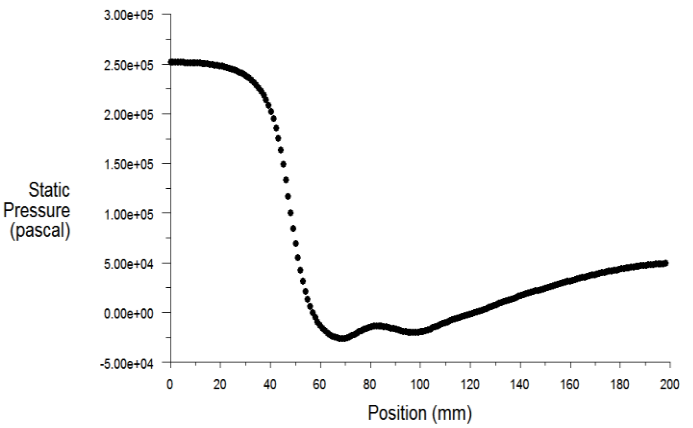


Figure 4. Static pressure along axis of CRMC jet ejector.

In a natural draught jet ejector there is large difference in kinetic energies of two streams before mixing occurs. So it leads to entropy generation. Forced draught is a new method adopted in this work to force the secondary fluid using a blower to the required velocity at the inlet of the secondary nozzle.

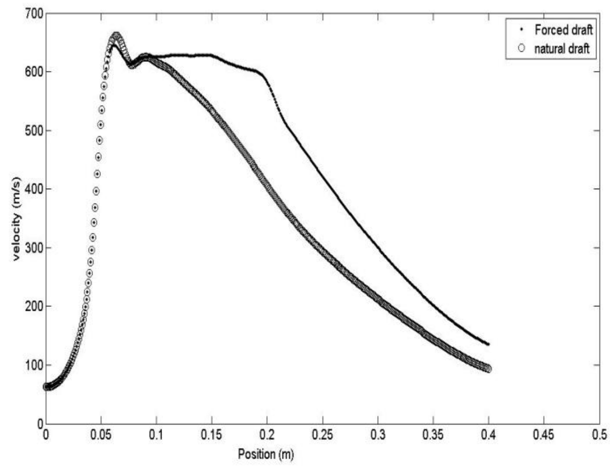


Figure.5. Variations of flow velocity at different sections of the jet ejector

The flow velocity plot obtained from the simulation results both for forced and unforced draft jet ejector are shown in figure (5). Since, the secondary fluid is forced externally using a blower, it is observed that the velocity of the motive fluid is almost maintained constant till the end of ejector throat compared to the natural draft system after an initial drop in velocity at the mixing section. This ensures a minimum momentum difference between the motive and the propelled fluid by which the entrainment ratio of the jet compressor is increased. In the diffuser section of the jet ejector the flow velocity of the mixed fluid decreases again to subsonic velocity converting the kinetic energy to pressure energy.

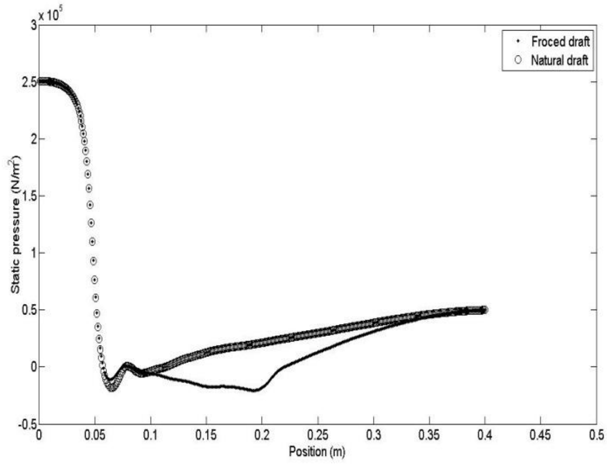


Figure 6. Comparison of variation of static pressure (gauge) of both the forced and unforced suction jet ejector.

Figure (6) shows the comparison of the static pressure change at different regions of the jet ejector for the forced and unforced draft system. In the forced suction, the static pressure is almost found constant for the entire mixing and the throat section after which it gradually rises in the diffuser section. This eliminates the shock process which occurs in the conventional method, avoiding the total pressure loss associated with the shock. The estimated pressure lift ratio using the CRMC method is found to increase by 40% over the conventional method.

8. Conclusion

In the present model, various losses have been identified and the performance of the jet ejector has been improved by using the concept of forced draught. Based on that, kinetic energy losses has been reduced, which in turn increased the efficiency of the jet compressor. In the present numerical study, entrainment ratio (ER) is increased from 0.774 to 0.95 due to forced draught. This obviously, reduces the irreversibility's of the jet compressor and shows good agreement with the theoretically designed value.

References

1. A.Arbel, A.Shklyar, D.Hershgal, M.Barak, M.Sokolov, "Ejector irreversibility characteristics", Journal of Fluid Engineering Vol. 125, 2003, page 121-1297.
2. Ian. W. Eames, "New prescription for the design of supersonic-jetpumps: the constant rate momentum change method", Applied thermal Engineering, Vol. 22, pp121-131, 2002
3. Somsak watanawanavet, "Optimization of high-efficiency jet ejector byComputational fluid dynamics software", Master of science thesis, Texas University, 2005.
4. S.B.Riffat, G.Gan and S.Smith, "Computational Fluid Dynamics applied to ejector heat pumps", Applied Thermal Engineering, Vol. 16, No 4, pp291-297, 1996.
5. Holtzapple, M. T., "High-Efficiency Jet Ejector," (Invention Disclosure) Department of Chemical Engineering, Texas A&M University, College Station, Texas (2001).
6. M.Ouzzane, Z.Aiddoum, "Model development and numerical procedure for detailed ejector analysis and design", Applied Thermal Engineering, Vol. 23, 2003, page 2337-2351.
7. G.K.Alexes, E.D.Rogdakis, "A. verification study of steam –ejector refrigeration model", Applied Thermal Engineering, Vol. 23, 2003, page 29-36.
8. Kanjanapon, Chunnanond, SathaApornratana, "An experimental investigation of a steam ejector refrigerator: the analysis of the pressure along the ejector", Applied Thermal Engineering, Vol. 24, 2004, page 311-322.
9. NabelBeithou, Hikmet S. Ayber, "A mathematical model for steam driven jet pump", international Journal of Multiphase flow, Vol. 26, 2000, page 1609-1619.