CFD ANALYSIS OF STEAM EJECTOR WITH DIFFERENT NOZZLE DIAMETER

G.Saidulu[1], A.Purender reddy[2], Shreenivas[3]

[1]*Student,Mech Dept,Sphoorthy Engineering College, Hyderabad,(India)*

[2]*Assistant professor,Mech Dept,Sphoorthy Engineering College, Hyderabad,(India)*

[3]*Assistant professor,Mech Dept,Sphoorthy Engineering College, Hyderabad, (India)*

ABSTRACT

A steam ejector is a device which utilizes the momentum of a high- velocity primary jet of vapor to entrain and accelerate a medium in still or at a low speed. The important functions of an ejector include maintaining vacuum in evaporation, removing air from condensers as a vacuum pump, augmenting thrust, and increasing vapor pressure as a thermal compressor. The thermal compressor is a steam ejector, but it utilizes the thermal energy to augment the performance by reducing the size of a conventional multi-stage evaporator. The effects on the primary fluid pressure, mass flow rate and Mach number were observed and analyzed. The Mach number contour lines were used to explain the mixing process occurring inside the ejector. In this thesis, we modeled steam ejector changing with different nozzle diameters and Analyzed the steam ejector with different mass flow rates to determine the pressure drop, Mach number, velocity and heat transfer rate for the primary fluid by CFD technique.

Key Words: Finite Element Analysis, Steam Ejector, Mach Number, Nozzle.

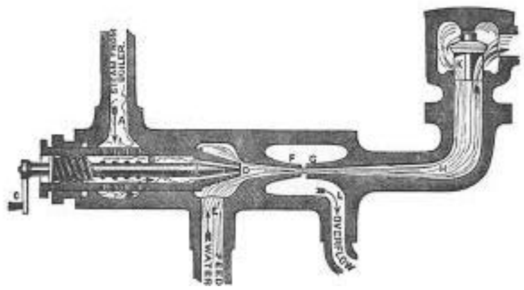
I. INTRODUCTION

Thermo compressors and ejectors operate on the same thermodynamic and physical principle: energy contained in high-pressure steam can be transferred to a lower pressure vapor or gas to produce a mixed discharge stream of intermediate pressure.

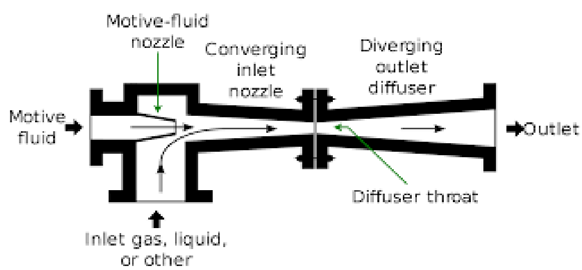
Steam ejectors are designed to convert the pressure energy of a motivating fluid to velocity energy to entrain suction fluid … and then to recompress the mixed fluids by converting velocity energy back into pressure energy. This is based on the theory that a properly designed nozzle followed by a properly designed throat or venture will economically make use of high pressure fluid to compress from a low pressure region to a higher pressure.

Steam ejectors: Steam jet ejectors offer a simple, reliable, low-cost way to produce vacuum. They are especially effective in the chemical industry where an on-site supply of the high-pressure motive gas is available. Ejectors are considered an alternative to mechanical vacuum pumps for a number of reasons: no source of power is required other than the motive gas; because they have no moving parts, they are reliable vacuum producers; they are easy to install, operate and maintain.

Steam ejector design: Very simply, an ejector is a pumping device. It has no moving parts. Instead, it uses a fluid or gas as a motive force. Very often, the motive fluid is steam and the device is called a "steam jet ejector." Basic ejector components are the steam chest, nozzle, suction, throat, diffuser and they discharge.



Ejectors designed in the critical range are sensitive to off-design operating conditions. Suction capacity cannot be increased. In fact, it is actually lowered by increasing the motive fluid pressure. Because the nozzle is a fixed orifice, any change in the motive fluid pressure will be accompanied by a proportionate change in the quantity of motive fluid. Changes are more gradual in non-critical design units but suction capacity still cannot be increased. The best solution is to be sure that service conditions are specified correctly.



II. LITERATURE REVIEW

EJECTORS USED IN AIR-CONDITIONING AND REFRIGERATION SYSTEMS

In the past, ejectors have mostly been used in two different cycles for refrigeration purposes. In 1910, Leblanc introduced a cycle having a vapor jet ejector. His setup allowed producing a refrigeration effect by utilizing low-grade energy. Since steam was widely available at that time, the so-called steam jet refrigeration systems became popular in air-conditioning of large buildings and railroad cars. The patent by Gay (1931) described how the two-phase ejector can be used to improve the performance of refrigeration systems by reducing the inherent throttling losses of the expansion valve.

2.1 Ejector for Recovery of Expansion Work

As already mentioned, a two-phase ejector can be used to improve the performance of a refrigeration system by reducing the throttling losses associated with the use of an expansion valve. The layout of such a transcritical R744 cycle and the corresponding pressure-specific enthalpy diagram are shown in Figure 5. It should be noted that the mass flow rate through the gas cooler is not identical to the evaporator mass flow rate. For this reason, Lorentz (1983) suggested to use a temperature-entropy diagram rather than a temperature-specific entropy diagram.

III. PROBLEM DESCRIPTION

Problem Description

The effects on the primary fluid pressure, mass flow rate and Mach number were observed and analyzed. The Mach number contour lines were used to explain the mixing process occurring inside the ejector.

Dia. Of nozzle (mm)	Pressure(mbar)
1.4, 1.7,2.0,2.4&2.6	20
	40
	60
	80

The methodology followed in the project is as follows:

- Create a 2D model of the steam ejector using parametric software pro-engineer.
- Convert the surface model into Para solid file and import the model into ANSYS to do analysis.

IV. INTRODUCTION TO CAD/CAE

Computer-aided design (**CAD**), also known as **computer-aided design and drafting** (**CADD**), is the use of computer technology for the process of design and design-documentation.

INTRODUCTION TO FINITE ELEMENT METHOD

Finite Element Method (FEM) is also called as Finite Element Analysis (FEA). Finite Element Method is a basic analysis technique for resolving and substituting complicated problems by simpler ones, obtaining approximate solutions Finite element method being a flexible tool is used in various industries to solve several practical engineering problems. In finite element method it is feasible to generate the relative results.

International Journal of Advanced Technology in Engineering and Science
Vol. No.5, Issue No. 03, March 2017
www.ijates.com
ijates
ISSN 2348 - 7550

V. RESULTS AND DISCUSSIONS

Models of steam ejector using pro-e wildfire 5.0: The steam ejector is modeled using the given specifications and design formula from data book.

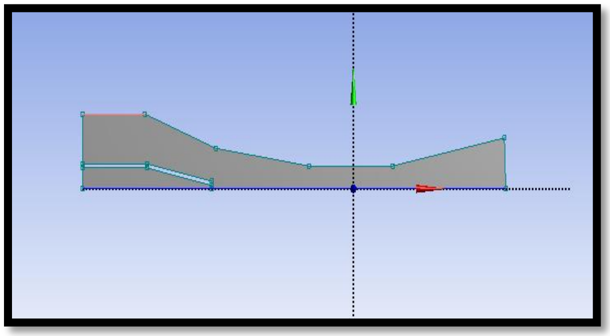
CFD ANALYSIS OF EJECTOR

CFD MODEL &ANALYSIS OF EJECTOR WITH NOZZLE DIA. 1.4

AT CONDENSER PRESSURE 20mbar

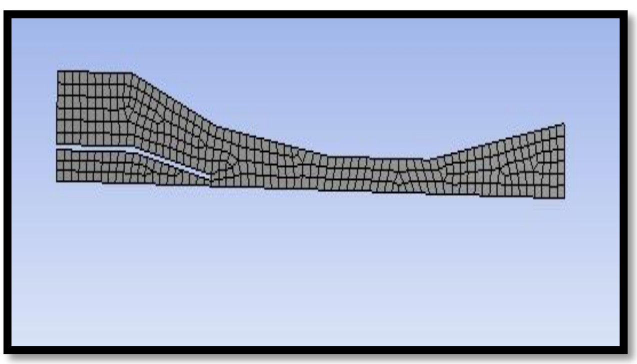
→→Ansys → workbench→ select analysis system → fluid flow fluent → double click

→→Select geometry → right click →new geometry

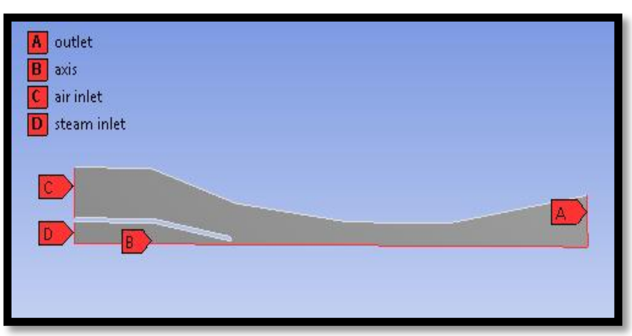


→→ Select mesh on work bench → right click →edit → select mesh on left side part tree → right click → generate mesh →

MESHED MODEL



SPECIFYING THE BOUNDARIES FOR INLET & OUTLET

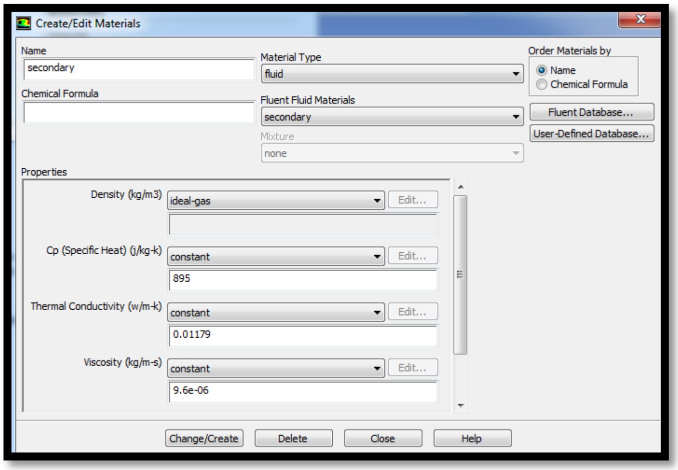


Update project>setup>edit>model>select>energy equation (on)>ok

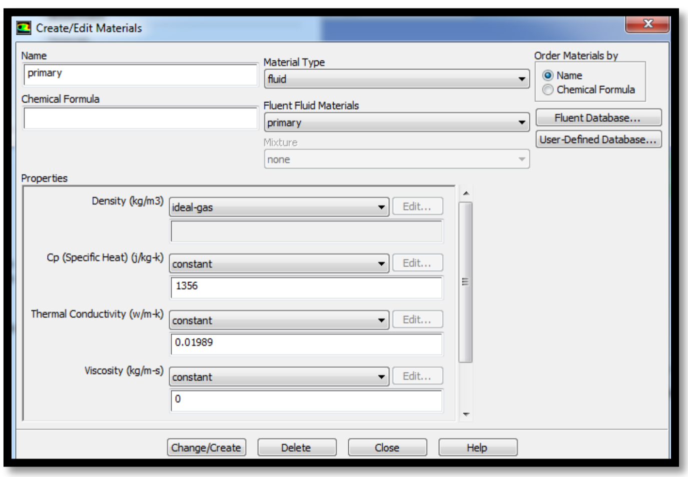
Materials> Materials > new >create or edit >specify fluid material or specify properties > ok

Select fluid

SECONDARY FLUID



PRIMARY FLUID



Boundary conditions>inlet>enter required inlet values

Mass flow rate = 4.6kg/hr

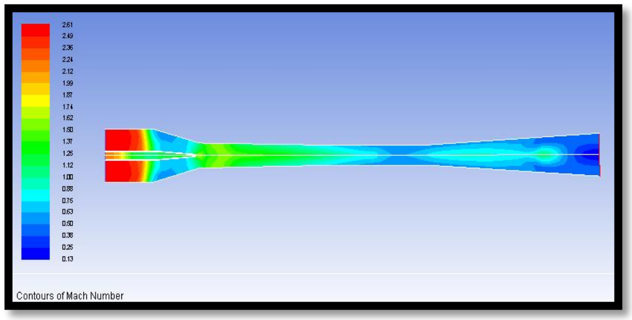
Condenser pressure=2000Pa

Temperature=150ºC

Solution > Solution Initialization > Hybrid Initialization >done

Run calculations > no of iterations = 10> calculate > calculation complete>ok

MACH NUMBER

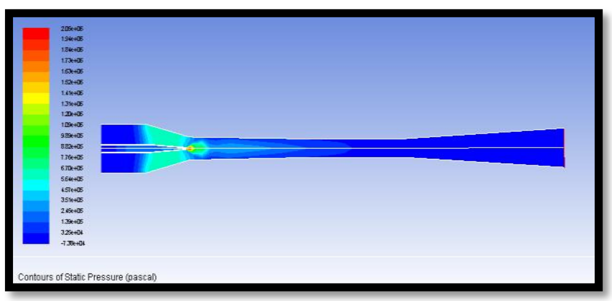


Mach number: In fluid dynamics, the **Mach number** (**M** or **Ma**) is a dimensionless quantity representing the ratio of flow velocity past a boundary to the local speed of sound.

According to the above contour plot, the maximum Mach number at steam ejector nozzle and secondary fluid inlet because the applying the boundary conditions at inlet of the steam ejector nozzle and minimum static pressure at the steam outlet.

According to the above contour plot, the maximum Mach number is 2.61 and minimum Mach number is 0.13.

PRESSURE



According to the above contour plot, the maximum static pressure inside of the steam ejector at nozzle because the applying the boundary conditions at inlet of the steam ejector nozzle and minimum static pressure at the steam outlet.

According to the above contour plot, the maximum pressure is 2.06e+06Pa and minimum static pressure is -7.38e+04Pa.

MASS FLOW RATE

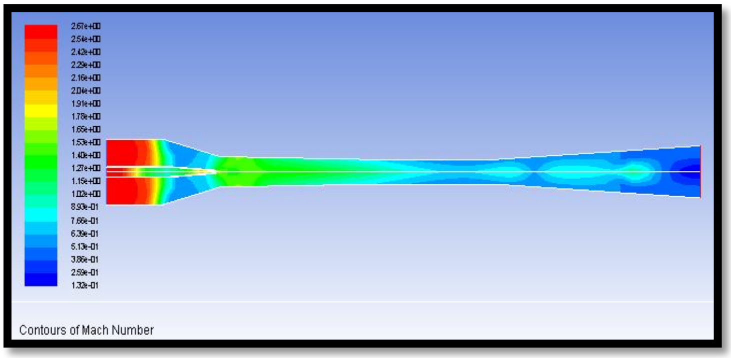
Mass Flow Rate	(kg/s)
interior-surface_body	150.24457
outlet	-2.6516879
primary_fluid_inlet	2.8721001
secondary_fluid_inlet	22.979748
wall-surface_body	0
Net	23.20016

International Journal of Advanced Technology in Engineering and Science
Vol. No.5, Issue No. 03, March 2017
www.ijates.com
ijates
ISSN 2348 - 7550

HEAT TRANSFER RATE

Total Heat Transfer Rate	(w)
outlet	-833107.88
primary_fluid_inlet	2385910.8
secondary_fluid_inlet	15385025
wall-surface_body	-0.0034130688
Net	16937828

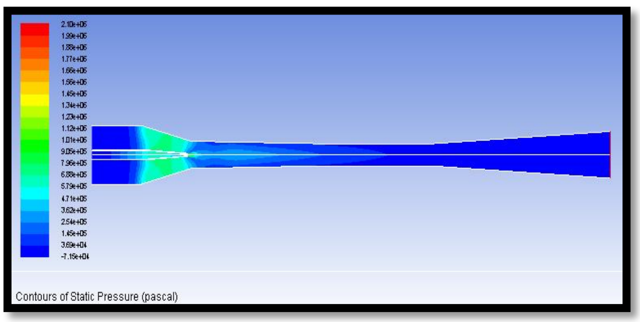
EJECTOR WITH NOZZLE DIA. 1.7 AT CONDENSER PRESSURE 20mbar MACH NUMBER



According to the above contour plot, the maximum Mach number at steam ejector nozzle and secondary fluid inlet because the applying the boundary conditions at inlet of the steam ejector nozzle and minimum static pressure at the steam outlet.

According to the above contour plot, the maximum Mach number is 2.67 and minimum Mach number is0 .132.

PRESSURE



According to the above contour plot, the maximum static pressure inside of the steam ejector at nozzle because the applying the boundary conditions at inlet of the steam ejector nozzle and minimum static pressure at the steam outlet.

According to the above contour plot, the maximum pressure is 2.10e+02Pa and minimum static pressure is -1.15e+04Pa.

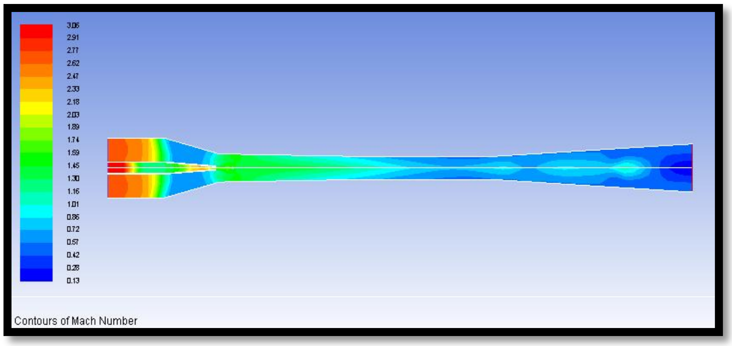
MASS FLOW RATE

Mass Flow Rate	(kg/s)
interior-surface_body	69.327461
outlet	-2.6806846
primary_fluid_inlet	3.5103445
secondary_fluid_inlet	23.502014
wall-surface_body	0
Net	24.331674

HEAT TRANSFER RATE

Total Heat Transfer Rate	(w)
outlet	-842112.75
primary_fluid_inlet	3618181.8
secondary_fluid_inlet	16153020
wall-surface_body	-0.0028015713
Net	18929089

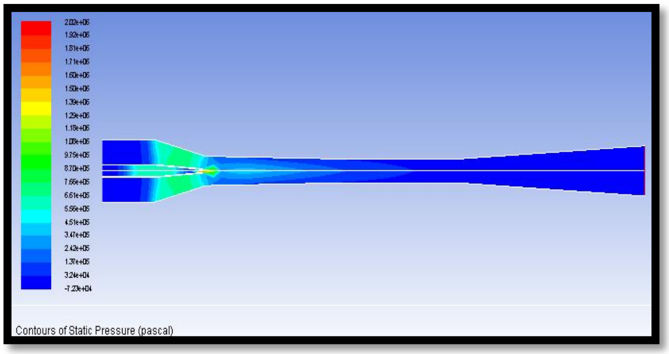
EJECTOR WITH NOZZLE DIA. 2.4 AT CONDENSER PRESSURE 80mbar MACH NUMBER



According to the above contour plot, the maximum Mach number at steam ejector nozzle and secondary fluid inlet because the applying the boundary conditions at inlet of the steam ejector nozzle and minimum static pressure at the steam outlet.

According to the above contour plot, the maximum Mach number is 3.06 and minimum Mach number is 0.13.

PRESSURE



According to the above contour plot, the maximum static pressure inside of the steam ejector at nozzle because the applying the boundary conditions at inlet of the steam ejector nozzle and minimum static pressure at the steam outlet.

According to the above contour plot, the maximum pressure is 2.02e+06Pa and minimum static pressure is -7.23e+04Pa.

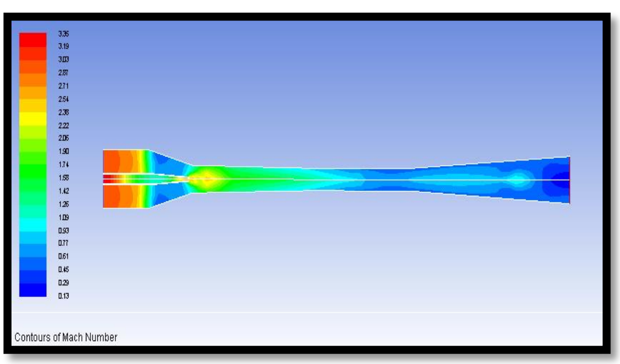
MASS FLOW RATE

Mass Flow Rate	(kg/s)
interior-surface_body	-127.34986
outlet	-2.6555085
primary_inlet	5.4105058
secondary_inlet	22.514067
wall-surface_body	0
Net	25.269064

HEAT TRANSFER RATE

Total Heat Transfer Rate	(w)
outlet	-848140
primary_inlet	6875237
secondary_inlet	15474000
wall-surface_body	-0.00028867798
Net	21501097

EJECTOR WITH NOZZLE DIA. 2.6 AT CONDENSER PRESSURE 80mbar MACH NUMBER

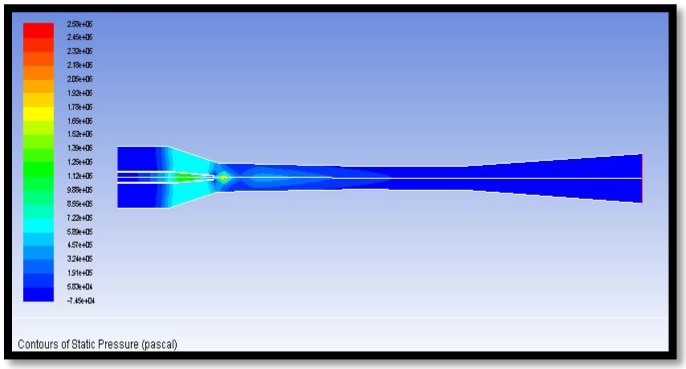


According to the above contour plot, the maximum Mach number at steam ejector nozzle and secondary fluid inlet because the applying the boundary conditions at inlet of the steam ejector nozzle and minimum static pressure at the steam outlet.

International Journal of Advanced Technology in Engineering and Science
Vol. No.5, Issue No. 03, March 2017
www.ijates.com
ijates
ISSN 2348 - 7550

According to the above contour plot, the maximum Mach number is 3.36 and minimum Mach number is 0.13.

PRESSURE



According to the above contour plot, the maximum static pressure inside of the steam ejector at nozzle because the applying the boundary conditions at inlet of the steam ejector nozzle and minimum static pressure at the steam outlet.

According to the above contour plot, the maximum pressure is 2.58e+06Pa and minimum static pressure is -7.45e+04Pa.

MASS FLOW RATE

```
                Mass Flow Rate                (kg/s)
-------------------------- --------------------
      interior-surface_body            250.10478
                     outlet           -2.6284237
        primary_fluid_inlet            5.3774734
      secondary_fluid_inlet            22.917698
          wall-surface_body                    0
           ---------------- --------------------
                        Net            25.666748
```

HEAT TRANSFER RATE

```
       Total Heat Transfer Rate                  (w)
-------------------------- --------------------
                     outlet           -834121.31
        primary_fluid_inlet              7559221
      secondary_fluid_inlet             15751416
          wall-surface_body        0.0025943378
           ---------------- --------------------
                        Net             22476516
```

5.1 Result Table

Dia. of the nozzle	Variables	20mbar	40mbar	60mbar	80mbar
1.4mm	Mach number	2.61	2.63	2.64	2.66
	Pressure(Pa)	2.06e+06	2.05e+06	2.11e+06	2.53e+06
	Mass flow rate(kg/s)	23.20016	23.330709	23.572439	23.70298
	Heat transfer rate(W)	16937828	17127213	1741065	17603554

Dia. of the nozzle	Variables	20mbar	40mbar	60mbar	80mbar
1.7mm	Mach number	2.67	2.696	2.70	2.727
	Pressure(Pa)	2.10e+06	2.14e+06	2.15e+06	2.20e+06
	Mass flow rate(kg/s)	24.331674	24.399621	24.728789	25.037949
	Heat transfer rate(W)	18929089	18999124	19463723	19935449

Dia. of the nozzle	Variables	20mbar	40mbar	60mbar	80mbar
2.0mm	Mach number	2.86	2.86	2.8	2.861
	Pressure(Pa)	1.23e+02	1.24e+06	1.25e+06	1.274e+06
	Mass flow rate(kg/s)	24.53676	24.610883	24.685005	24.759128
	Heat transfer rate(W)	19664796	19749721	19834647	19919572

Dia. of the nozzle	Variables	20mbar	40mbar	60mbar	80mbar
2.4mm	Mach number	3.06	3.0534	3.0989	3.06
	Pressure(Pa)	1.93e+06	1.96e+06	1.99e+06	2.02e+06
	Mass flow rate(kg/s)	24.972133	25.07111	25.170087	25.269064
	Heat transfer rate(W)	21123772	21249547	21375322	21501097

Dia. of the nozzle	Variables	20mbar	40mbar	60mbar	80mbar
2.6mm	Mach number	3.23	3.29	3.32	3.36
	Pressure(Pa)	2.53e+06	2.86e+06	2.86e+06	2.58e+06
	Mass flow rate(kg/s)	25.371643	25.470023	25.568386	25.666748
	Heat transfer rate(W)	22061656	22199947	22338232	22476516

VI CONCLUSION

The effects on the primary fluid pressure, mass flow rate and Mach number were observed and analyzed. The Mach number contour lines were used to explain the mixing process occurring inside the ejector.

In this thesis, we modeled steam ejector changing with different nozzle diameters and Analyzed the steam ejector with different mass flow rates to determine the pressure drop, Mach number, velocity and heat transfer rate for the primary fluid by CFD technique.

By observing the CFD analysis the Mach number, pressure drop, heat transfer rate and mass flow rate increases by increasing the diameter of the nozzle and condenser pressure. So it can be conclude the steam ejector nozzle diameter 2.6mm is better model.

REFERENCES

1. Analysis of steam ejector by using computational fluid dynamics dr.i satyanarayana1
2. Thermal Analysis of Steam Ejector Using CFD T.Aravind 1 , Dr P Ravinder Reddy 2 , S S Baserkoed
3. CFD simulation on the effect of primary nozzle geometries for a steam ejector in refrigeration cycle Natthawut Ruangtrakoon a, Tongchana Thongtip a , Satha Aphornratana a,*, Thanarath Sriveerakul b.
4. Numerical Study on the Supersonic Steam Ejector Use in Steam Turbine System Lin Cai and Miao He
5. Keenan, JH and NeumannEP (1950), An Investigation of Ejector Design by Analysis and Experiment, J Applied Mechanics, Trans ASME, 72, 299-309
6. Xianchang Li, Ting Wang and Benjamin Day (2010), Numerical analysis of the performance of a thermal ejector in a steam evaporator,Applied Thermal Engineering, 30,2708-2717
7. Tony Utomo, Myongkuk Ji, Pilhwan Kim, Hyomin Jeong and Hanshik Chung (2008), CFD Analysis on the Influence of Converging Duct Angle on the Steam Ejector Performance, International Conference on Engineering Optimization
8. Hisham El-Dessouky , Hisham Ettouney, Imad Alatiqi and Ghada Al-Nuwaibi (2002), Evaluation of steam jet ejectors,Chemical Engineering and processing,41,551–561
9. ED Rogdakis and GK Alexis (2000) Design and parametric investigation of an ejector in an airconditioning system, Applied Thermal Engineering, 20, 213-226
10. Narmine H Aly, Aly Karameldin and MM Shamloul (1999), Modelling and simulation of steam jet ejectors, Desalination, 123, 1-8
11. BJ Huang and JM Chang (1999), Empirical correlation for ejector design, International Journal of Refrigeration, 22,379–388

	G SAIDULU received his B.Tech degree in Mechanical Engineering in 2013 and M.Tech Degree persuing in Thermal Engineering in Sphoorthy Engineering College (MECH Dept) Hyderabad. His Area of interest is Flexible in Thermal science.
	ANNREDDY PURENDER REDDY received his B.Tech degree in Mechanical Engineering in 1996 and M.Tech Degree in Energy Systems in 2011.Presently working as an Assistant Professor in Sphoorthy Engineering College (MECH Dept) Hyderabad. His Area of interest Design and gear manufacturing.

	SHREENIVAS received his B.E degree in Mechanical Engineering in 2013 and M.Tech Degree in Thermal Power Engineering in 2015.Presently working as an Assistant Professor in Sphoorthy Engineering College (MECH Dept) Hyderabad. His Area of interest is Flexible in I.C. Engines ,heat transfer, .