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A Performance CFD Investigation of Steam Ejector with Different Nozzle Diameter

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Abstract:*A steam ejector is a device which makes use of the momentum of a high- pace number one jet of vapor to entrain and accelerate a medium in still or at a low speed. The vital functions of an ejector include maintaining the vacuum evaporation, doing away with air from condensers as a vacuum pump, augmenting thrust, and growing vapor stress as a thermal compressor. The thermal compressor is a steam ejector, however, it utilizes the thermal strength to reinforce the overall performance by means of decreasing the scale of a conventional multi-degree evaporator. The supersonic steam ejector is extensively utilized in steam energy structures inclusive of refrigeration, wood drying gadget, papermaking machine, and steam turbine. In this paper the Computational Fluids Dynamics (CFD) method became hired to simulate a supersonic steam ejector, SST okay-w turbulence model became followed, and each actual fuel model and the ideal gas version for the fluid belongings had been considered and as compared. The blending chamber attitude, throat period, and nozzle go out function number one pressure and temperature results on entrainment ratio had been investigated. The Static pressure to the boiler temperatures 120^{o}C,130^{o}C, and one hundred forty ^{o}C. In this mission the 2D version is achieved in PRO-E software and analysis completed in ANSYS 14.5*

Keywords- Symmetric model, Ejector, Entrainment ratio, Throat diameter, Condenser pressure.

I. INTRODUCTION

A steam ejector is a device which makes use of the momentum of a high- pace primary jet of vapor to entrain and accelerate a medium in still or at a low speed. The essential functions of an ejector consist of maintaining the vacuum evaporation, eliminating air from condensers as a vacuum pump, augmenting thrust, and growing vapor pressure as a thermal compressor. The thermal compressor is a steam ejector, however, it makes use of the thermal energy to reinforce the performance by way of lowering the scale of a conventional multi-level evaporator. The consequences of the primary fluid stress, mass glide rate, and Mach wide variety have been discovered and analyzed. The Mach variety contour lines had been used to provide an explanation for the mixing process going on inside the ejector. In this thesis, we modeled steam ejector changing with distinctive nozzle diameters and Analyzed the steam ejector with exceptional mass drift prices to determine the stress drop, Mach wide variety, pace, and warmth transfer charge for the number one fluid by CFD approach. This work makes a specialty of the numerical simulation of the operating of a steam ejector so as improve the performance. Computational Fluid Dynamics (CFD) turned into employed for the numerical simulation. In this work, the effect of operating conditions on the performance of the steam ejector operating together with an ejector refrigeration cycle turned into taken into consideration alongside the effect of geometry parameter. The version and meshing are completed with GAMBIT and the FLUENT solver is used for the evaluation. The simulations are finished under special running situations and geometries. The entrainment ratio is observed to increase with the decrease of boiler saturation temperature for the identical circumstance of superheat, evaporator temperature and condenser strain. The entrainment ratio is likewise discovered to increase with the boom of evaporator temperature retaining the boiler temperature and condenser stress constant. The entrainment ratio does now not very plenty of the condenser pressure until the vital condenser stress. It is also determined that the entrainment ratio increases with the decrease of throat diameter of the number one nozzle. The growth of entrainment ratio can be located out from the transferring downwards of the effective function. But, a bigger mass of secondary fluid reasons the momentum of the blended circulation to decrease. The decrease of momentum can be determined from the transferring upstream of the shocking function. The motion of surprising role upstream can reason the ejector to perform at a decrease important condenser strain.

II. RELATED WORK

At the same time, researchers started to investigate its working mechanism. Keenan and Neumann [1] presented the first comprehensive theoretical and experimental analysis of the ejector problem. Xianchang Li et al. [2] carried out a numerical analysis to study about the influence of geometric arrangement on the performance of steam ejector used in conjunction with a steam evaporator. It is observed that any downstream resistance will seriously impede the suction flow rate. In addition, the entrainment ratio is sensitive to the location of the jet exit, and there is an optimum location where the primary flow should be issued. Tony Utomo et al. [3] in their study the use of steam ejector in desalination system, particularly multi effect desalination (MED) system. In this study, CFD (computational fluid dynamics) analysis based on the finite volume method was employed to investigate the influence of angle of converging duct on the ejector performance. Hisham El-Dessouky et al. [4] studied using semi-empirical models design and rating of steam jet ejectors. The model gives the entrainment ratio as a function of the expansion ratio and the pressures of the entrained vapour, motive steam and compressed vapour E.D.

Rogdakis et al. [5] discusses the behaviour of ammonia (R-717) through an ejector operating in an air-conditioning system with a low temperature thermal source. The influence of three major parameters: generator, condenser and evaporator temperature, on ejector efficiency and coefficient of performance is discussed. Narmine H. Aly et al. [6] studied a computer simulation model for steam jet ejectors. The model was developed by application of the equations of continuity, momentum and energy to individual operation of nozzle, mixing chamber and diffuser. B.J. Huang et al. [7] studied, two empirical correlations from the test results of 15 ejectors are derived for the performance prediction of ejectors using R141b as the working fluid. Kanjanapon Chunnanond et al. [8] studied the methods to increase the efficiency of an ejector refrigerator, a better understanding of the flow and the mixing through an ejector is needed. Shengqiang Shen et al. [9] studied a new configuration of a bi-ejector refrigeration system. The purpose of one is to drink refrigerant vapour from the evaporator and discharge to the condenser; the other acts as a jet pump to pump liquid refrigerant from the condenser to the generator. Y. Bartosiewicz et al. [10] studied numerical results of a supersonic ejector for refrigeration applications. E. Rusly et al. [11] modeled ejector designs using finite volume CFD techniques to resolve the flow dynamics in the ejectors. Szabolcs Varga et al. [12] studied about factors influencing the performance of an ejector. In this work, three geometrical factors – the area ratio between the nozzle and constant area section, nozzle exit position and constant area section length were considered.

III. CFD SIMULATION OF THE STEAMEJECTOR

The dimension of the ejector which is used for the analysis is considered from the Ref[8] and is shown in Fig. 1 and thethree different primary nozzle dimensions (Fig.2) which are used for the analysis is given in table1. The detaileddimensions of steam ejector are used to build the geometry in Gambit software. The other important dimensions forcreating the geometry were assumed: Suction inlet diameter = 49.2mm, Ejector outlet diameter = 40mm, Length ofstraight cross section after the diffuser = 20mm. The steam ejector model was developed using GAMBIT 2.4.6 software.Three 2-D Axis Symmetrical model was created according to the three primary nozzle dimension specified The model isthen meshed using GAMBIT and the mesh near to the wall was refined using boundary layer meshing is given in Fig. 3.The analysis was carried out in the commercial CFD package named FLUENT software. The geometry and gridsystem were imported to the solver FLUENT 6.3.26. The wall was set to be a stationary, non-slip wall. The fluid inthe domain was set to be water vapour properties being constant. A pressure-based was used for

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all calculation cases.The "2-D axis-symmetric" model was adopted as the spatial approach.

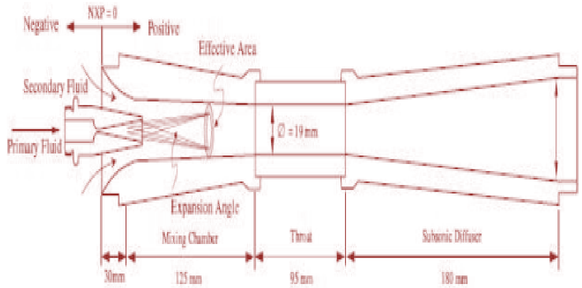


Fig.1 Steam ejector dimensions from Ref [8]

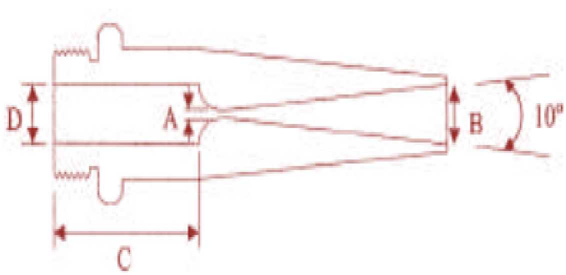
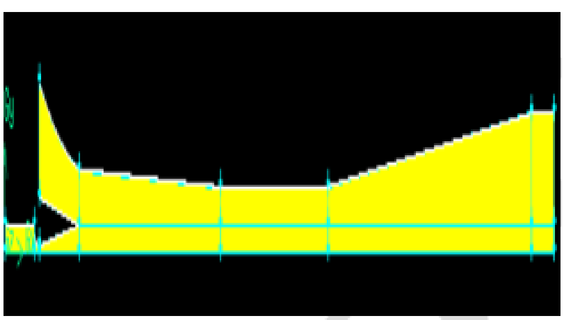


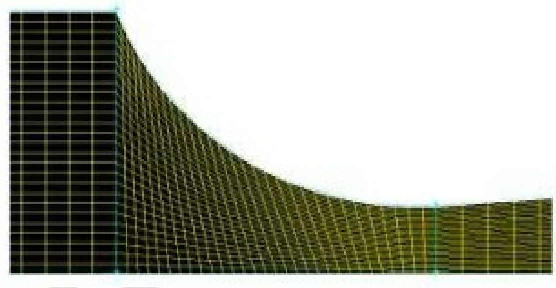
Fig.2 Primary nozzle dimensions

The fluid flow was set as steady state. ThoughReynolds number could be low in certain areas, the flow is generally turbulent in the computational domain. SpalartAllmaras turbulence model, with "Vorticity" as eddy generation method, was employed for all calculations. Energyequation was enabled.



a. Geometric model

The convergence criteria used for the analysis were: Continuity: 1e-05 X-velocity, 1e-06, Yvelocity, 1e-06, Energy: 1e-06 Nut: 1e-04, once the properties were evaluated, the data points were written in a file. The properties for fluid and solid are given in table 2 represents the domain considered as aluminum and flow is fluidproperties are mentioned for the analysis.



b. Meshed model

Fig.3 The geometric and meshed model of steam ejector

Table1. Primary nozzle dimensions

Nozzle no.	Geometry, mm			
	A	B	C	D
1	2.00	8.00	25.70	7.75
2	1.75	7.00	25.70	7.75
3	0.50	6.00	25.70	7.75

Table2. The properties of fluid and aluminium

Property	Fluid	Aluminum
Density, kg/m3	1.225	2719
Specific Heat(C_p), j/kg-k	1006.43	871
Thermal Conductivity, w/m-k	0.0242	180
Viscosity, kg/m-s	1.7894e-05	-
Molecular Weight, kg/kgmol	28.966	

The primary inlet and secondary inlet were taken as pressure inlet and the ejector outlet was taken as pressure outlet.The axis was defined as the axis boundary type. And the wall boundary type was used to define the entire outergeometry. The boundary conditions employed to compare the performance of the three different geometries are forPrimary inlet: Boiler temperature is 130^0C at 232.23 kPa and the secondary inlet the evaporator temperature is 50C at800 Pa and the ejector outlet the condenser pressure is 35 mbar. Further the

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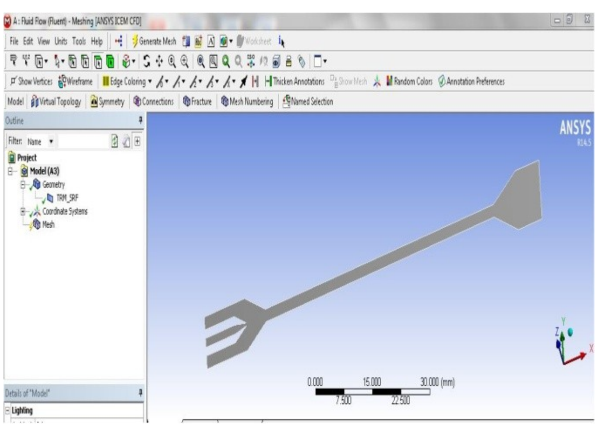
different operating conditions employedto compare the performance of the steam ejector are: a) Effect of condenser pressure, b) Effect of boiler temperatureand c) Effect of evaporator temperature.

a) Effect of condenser pressure: The boundary conditions used for this analysis are at the primary inlet the boilertemperature is 130^{0}C at 232.23 kPa, at the secondary inlet the evaporator temperature is 100C at 1200Pa and at theEjector outlet three different cases of condenser pressure are considered 25 mbar, 35 mbar and 45mbar. b) Effect ofboiler temperature: The boundary conditions used for this analysis are at the primary inlet three different cases ofboiler temperature are considered 1200C, 1300C and 1400C respectively at 169.18 kPa, 232.23 kPa and 313.22 kPa atthe secondary inlet the evaporator temperature is 150C at 1700Pa and at the ejector outlet the condenser pressure of45 mbar. c) Effect of evaporator temperature: The boundary conditions used for this analysis are at the primary inletthe boiler temperature is 1200C at 169.18 kPa, at the secondary inlet the three different cases of evaporatortemperature are considered 50C, 100C and 150C respectively at 800 Pa, 1200 Pa and 1700 Pa and at the Ejector outletthe condenser pressure of 25 mbar.

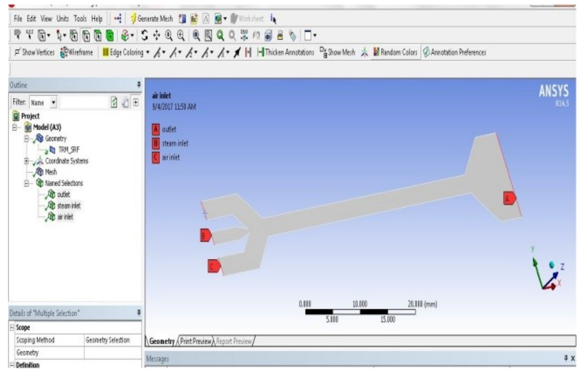
IV. SIMULATIONANALYSIS

→→Ansys → workbench→ select analysis system → fluid flow fluent → double click →→Select geometry → right click →new geometry

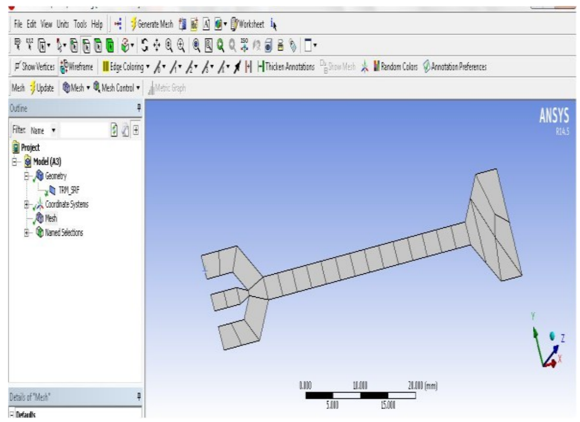


→→ Select mesh on work bench → right click →edit → select mesh on left side part tree → right click → generate mesh →

Inlet and outlet



Meshed model



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

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

V. CONCLUSION

In this paper, we modeled steam ejector changing with different nozzle diameters and examined the steam ejector with different pressure costs to determine the pressure drop, pace and heat transfer charge for the primary fluid by using CFD technique. By using looking at the CFD evaluation the considerable amount, strain drop, heat transfer rate and mass drift rate increases through increasing the diameter of the nozzle and condenser strain. So it could be finish the steam ejector nozzle diameter 2.4mm is higher version.

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