CFD ANALYSIS OF STEAM EJECTOR WITH DIFFERENT NOZZLE DIAMETER

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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 project, 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.

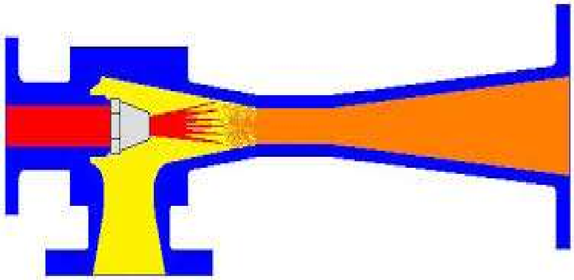
Key words: steam ejector, mach number, CFD analysis.

I. INTRODUCTION TO EJECTORS

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. This change from pressure head to velocity head is the basis of the jet vacuum principle. Ejectors are generally categorized into one of four basic types: single-stage, multi-stage non-condensing, multi-stage condensing and multi-stage with both condensing and no condensing.

II. WORKING OF EJECTOR

All ejectors operate on a common principle. The unmarried stage ejector, in its simplest shape, consists of an actuating nozzle, suction chamber and a diffuser. The actuating fluid, which may be a gas, vapor or liquid, is increased from its initial pressure to a stress identical to that of the secondary fluid. In the technique of being extended, the actuating fluid is elevated from its preliminary front pace, which is negligibly small, to a high velocity. In the suction chamber, the actuating fluid induces a region of low strain-excessive speed glide which reasons the secondary fluid to come to be entrained and combined with the actuating fluid. During the combination manner, the actuating fluid is retarded and the secondary fluid is multiplied. As the combination enters the diffuser, it's miles compressed to the go out pressure with the aid of rapid deceleration. The reason of the ejector is to transport and compress a weight of brought on fluid from the suction stress to the exit strain.



III. LITERATURE REVIEW

Analysis of steam ejector by using computational fluid dynamics by Dr.I. satyanarayana principal &professor of mechanical engineering. Ejectors are widely used in many applications such as water desalination, steam turbine, refrigeration systems, and chemical plants..this project work carries the numerical simulation of the working of a steam ejector in order improve the performance. Computational fluid dynamics (CFD) was employed for the numerical simulation. In this paper the effect of operating conditions on the performance of the steam ejector operating in conjunction with an ejector refrigeration cycle was considered.

IV. PROCEDURE

Creating a surface model a two dimensional surface model of steam ejector is created on the computer using ANSYS, to CFD for performing finite element analysis.

Finite element analysis there are three main steps, namely: pre-processing, solution and post processing. In pre-processing (model definition) includes: define the geometric domain of the problem, the element type(s) to be used, the material properties of the elements, the geometric properties of the elements (length, area, and the like), the element connectivity (mesh the model), the physical constraints (boundary conditions) and the loadings. In solution phase, the governing algebraic equations in matrix form are assembled and the unknown values of the primary field variable(s) are computed. The computed results are then used by back substitution to determine additional, derived variables, such as reaction mass flow inlets and heat flow. Actually, the features in this step such as matrix manipulation, numerical integration and equation solving are carried out automatically by commercial software. In post processing, the analysis and evaluation of the result is conducted in this step.

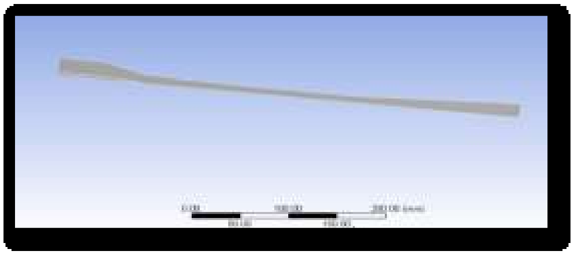
V. CFD MODELLING

The ejector is modeled as a 2D axi-symmetric model . Grid independent studies are performed using quadrilateral gird structure with mesh size of 0.65mm by refining mesh after every simulation to obtain grid independent results. The number of cells for computations was varied from 20,000 to 70,000. The results with approximately 52,000 elements were found to be independent of the grid size, since fundamental information was not lost. The grid density was made finer on the areas where ever significant changes in property values were expected. In the CFD simulation process, choice of a suitable turbulence model also plays an important part in order to get reasonably good results. Standard K-ε model is used in the analysis. In the present study, it is found that there is not much variation in Mach number either by using standard k-ε or by using realizable model.

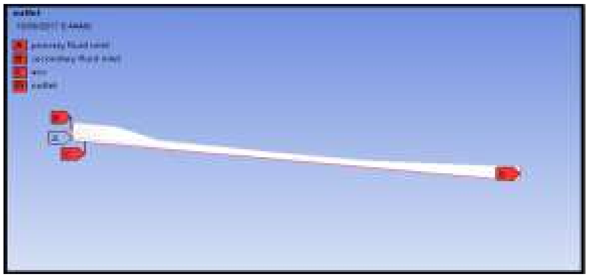
VI. CFD ANALYSIS OF EJECTOR

CFD model &analysis of ejector with nozzle dia. 1.4 mm

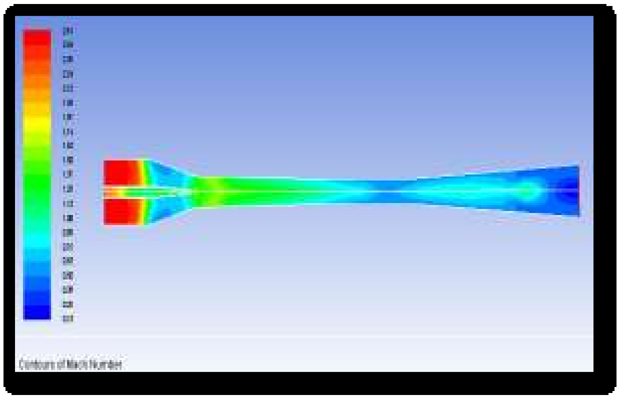
At condenser pressure 20mbar



Specifying the boundaries for inlet & outlet



Mach number

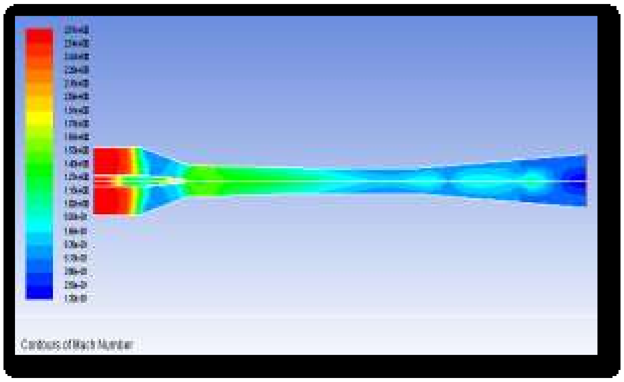


Mach wide variety: in fluid dynamics, the mach range (m or ma) is a dimensionless amount representing the ratio of go with the flow pace past a boundary to the nearby speed of sound.

Ejector with nozzle dia. 1.7 mm

At condenser pressure 20mbar

Mach number

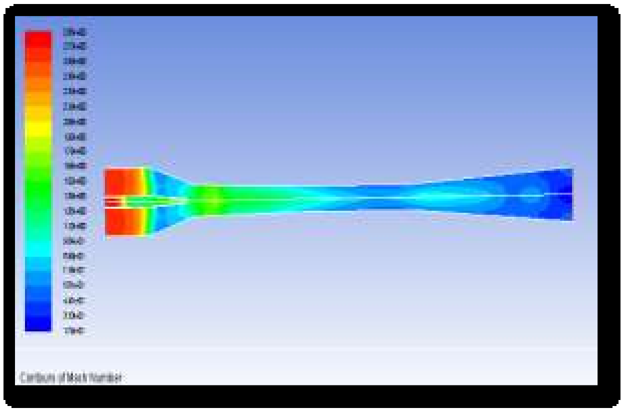


According to the above contour plot, the most mach variety at steam ejector nozzle and secondary fluid inlet because the making use of the boundary conditions at inlet of the steam ejector nozzle and minimal static stress at the steam outlet.

Ejector with nozzle dia. 2.0mm

At condenser pressure 20mbar

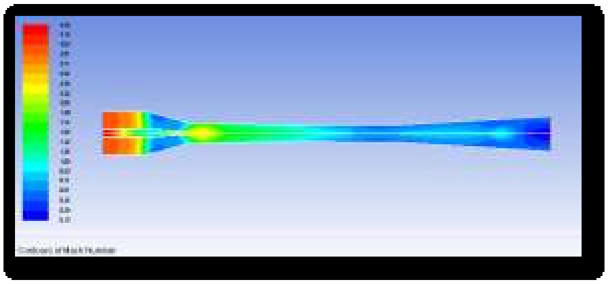
Mach number



According to the above contour plot, the most mach variety at steam ejector nozzle and secondary fluid inlet because the making use of the boundary conditions at inlet of the steam ejector nozzle and minimal static stress at the steam outlet.

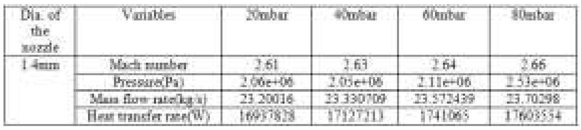
At condenser pressure 80mbar

Mach number



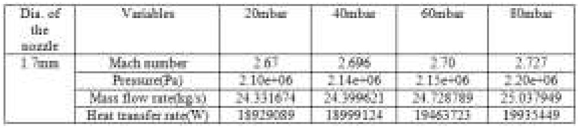
According to the above contour plot, the most mach variety at steam ejector nozzle and secondary fluid inlet because the making use of the boundary conditions at inlet of the steam ejector nozzle and minimal static stress at the steam outlet.

VII. RESULTS TABLES



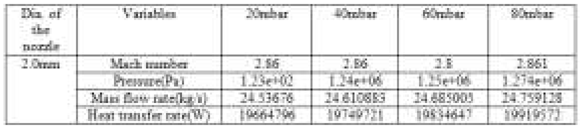
Dia. of the nozzle	Variables	20mbar	40mbar	60mbar	80mbar
1.4mm	Mach number	2.61	2.63	2.64	2.66
	Pressure(Pa)	2.06e+06	2.05e+06	2.11e+06	2.53e+06
	Mass flow rate(kg/s)	23.20016	23.330709	23.572439	23.70298
	Heat transfer rate(W)	16937828	17127213	1741063	17603554

According to the above table the heat transfer rate value increased by increasing the condenser pressure in steam ejector i.e., 17603554w.



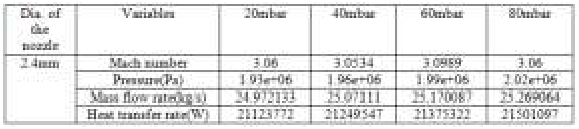
Dia. of the nozzle	Variables	20mbar	40mbar	60mbar	80mbar
1.7mm	Mach number	2.67	2.696	2.70	2.727
	Pressure(Pa)	2.10e+06	2.14e+06	2.15e+06	2.20e+06
	Mass flow rate(kg/s)	24.331674	24.399621	24.728789	25.037949
	Heat transfer rate(W)	18929089	18999124	19463723	19935449

According to the above table the heat transfer rate value increased by increasing the condenser pressure in steam ejector i.e., 19935449w.



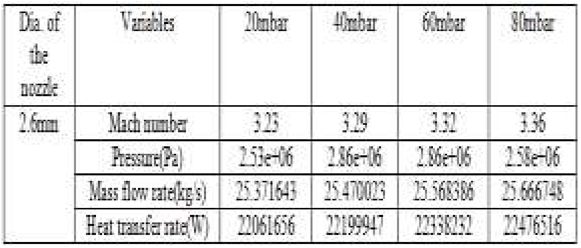
Dia. of the nozzle	Variables	20mbar	40mbar	60mbar	80mbar
2.0mm	Mach number	2.86	2.86	2.8	2.861
	Pressure(Pa)	1.23e+02	1.24e+06	1.25e+06	1.274e+06
	Mass flow rate(kg/s)	24.53676	24.610883	24.685003	24.759128
	Heat transfer rate(W)	19664796	19749721	19834647	19919572

According to the above table the heat transfer rate value increased by increasing the condenser pressure in steam ejector i.e., 19919572w.



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	25.07311	25.170087	25.269064
	Heat transfer rate(W)	21123772	21249547	21375322	21501097

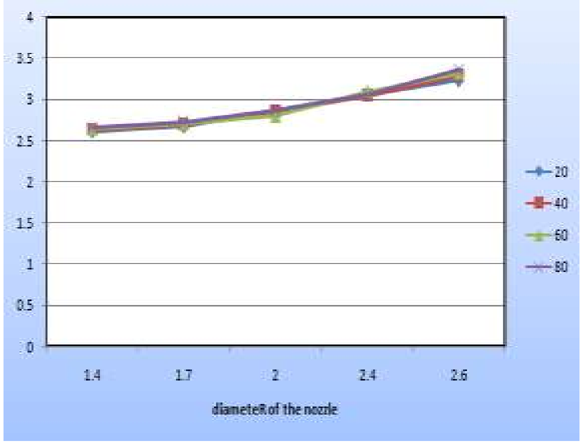
According to the above table the heat transfer rate value increased by increasing the condenser pressure in steam ejector i.e., 21501097w.



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

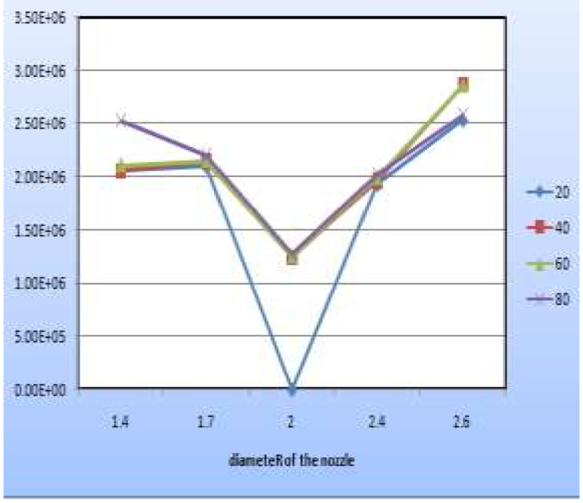
According to the above table the heat transfer rate value increased by increasing the condenser pressure in steam ejector i.e., 22476516w.

MACH NUMBER PLOT



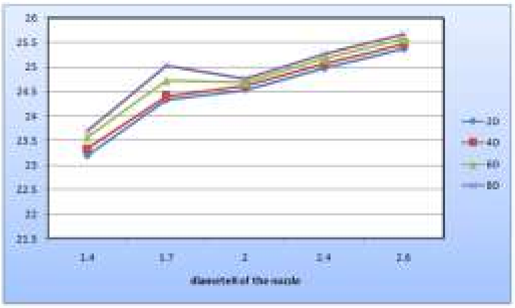
according to above plot the mach number increases by increasing diameter of nozzle when we plotted mach number Vs nozzle diameter.

PRESURE PLOT



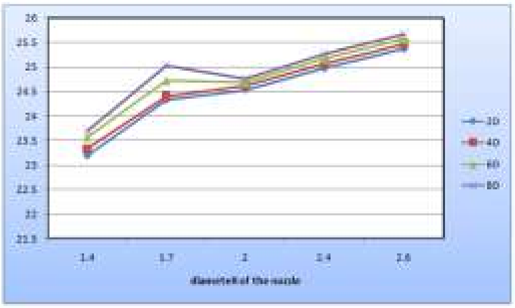
according to above plot the pressure increases by increasing diameter of nozzle when we plotted pressure Vs nozzle diameter.

MASS FLOW RATE PLOT



according to above plot the mass flow rate increases by increasing diameter of nozzle when we plotted mass flow rate Vs nozzle diameter.

HEAT TRANSFER RATE



according to above plot the heat transfer rate increases by increasing diameter of nozzle when we plotted heat transfer rate Vs nozzle diameter.

VIII. CONCLUSION

In this thesis, we modeled steam ejector changing with different nozzle diameters(1.4,1.7,2.0,2.4 and 2.6mm) 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. Heat transfer rate values are more for condenser pressure 80mbar and 2.6mm steam ejector nozzle diameter. So it can be concluded the steam ejector nozzle diameter 2.6mm is better model.

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