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CFD Analysis of Ejector Using Different Refrigerants: R141b, R152a, R134a

Gajendra Singh Tomar[1], Adarsh Partap Singh Bais[2], Ankit Patidar[3], Devanand Patel[4],
Lokesh Aurangabadkar[5], Dr. D V Singh[6]
[1,2,3,4] UG student, Department of Mechanical Engineering, IIST, Indore, India
[5]Assistant Professor, Department of Mechanical Engineering, IIST, Indore, India
[6]Associate Professor, Department of Engineering, IIST, Indore, India

Abstract : Supersonic ejectors are broadly utilized in a extend of applications such as aviation, impetus, and refrigeration. The essential intrigued of this think about is to set up dependable hydrodynamics demonstrate of a supersonic ejector, which may be amplified to refrigeration applications. From the early 1900s, Supersonic Ejectors have been utilized in cooling/refrigeration applications. This project shows the results of computational fluid dynamics (CFD) simulations of a supersonic ejector for use in a refrigeration system. The proposed model was applied to a geometry corresponding to an experimental apparatus that operates using R141b, R152a, R134a. The impact of varying operating conditions pressure, velocity, density, the temperature was investigated in the different refrigerants. The results show that CFD is a useful tool in the design of ejectors for refrigeration applications.

***IndexTerms* - Pressure,velocity,density,temperture,CFD,refrigeration.**

History of Ejector Refrigeration

Giffard designed the condensing ejector in 1858. Kranakis (1982) gave an awfully nitty gritty outline of his groundbreaking work. The foundation of Giffard’s development was to discover a arrangement to the issue of bolstering liquid water to recharge the store of steam motor boilers. Other than being not exceptionally dependable, mechanical pumps required the steam motor to move in arrange to supply water to the evaporator.This characteristic impediment might be overcome with Giffard’s ejector, since the thought process steam required to pump fluid water was moreover accessible amid standstill. In spite of the fact that supersonic stream at the exit of the thought process spout would have been best, Giffard and other early ejector originators utilized merging thought process spouts. The converging-diverging rationale spout was not presented until 1869 by an design named Schau. Interests, this shows up to be indeed prior than de Laval’s work, who carried out his to begin with supersonic steam spout tests in 1890. He altered his unique ejector plan by coordination a axle valve which can be axially moved to control the motive flow rate.

Principle of Ejector

Ejector refrigeration system uses an ejector, a fluid pump and a vapor generator to supplant the mechanical compressor. Fig.1 outlines a simple ejector refrigeration system with its major components named. The generator gets heat from a low-cost, low-grade thermal energy source and heats up the refrigerant to create high pressure and high temperature vapor known as the primary liquid that enters the ejector and quickens through the ejector nozzle where the jet issuing from it entrains the low-pressure secondary flow coming from the evaporator. The two major characteristics which can be utilized to determine the performance of an ejector

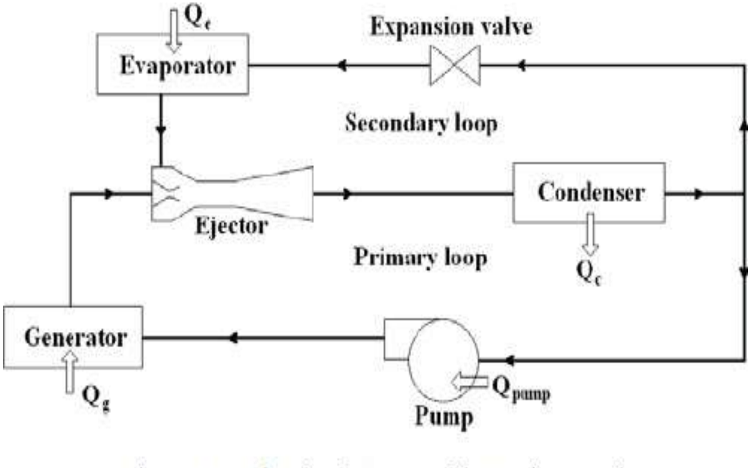


Figure 1: A basic ejector refrigeration cycle.

are the suction pressure ratio and the mass entrainment ratio. The suction pressure ratio is characterized as the ratio of diffuser exit pressure to the pressure of the suction flow entering the ejector. The mass entrainment ratio is characterized as the ratio of suction mass flow rate to thought process mass stream rate. A well-designed ejector is able to supply large suction pressure ratios and large mass entrainment ratios at the same time.

The system's execution is best depicted by its Coefficient of Execution (COP) and the ejector's entrainment proportion (ER). Numerically, they are characterized as,

Computational Fluid Dynamics (CFD)

The governing equations for fluid flow such as conditions for conservation of mass, momentum, and energy form a set of coupled, nonlinear fractional differential conditions. Explanatory methods may not be conceivable to illuminate these equations for most engineering issues but, computational fluid dynamics is competent of managing with these sorts of equations.

$$COP = \frac{Q_E}{Q_g + W_p} \qquad ER = \frac{\dot{m}_s}{\dot{m}_p}$$

CFD could be a department of fluid mechanics and is the science of foreseeing fluid flow, heat and mass exchange, chemical reactions, and related wonders. The domain is discretized into limited sets of control volume where the conditions within the frame of Navier -Stokes partial differential equations are solved.These equations are changed over into a set of arithmetical equations at discrete focuses which are at that point solved numerically to render a arrangement with the suitable boundary conditions.

Fluid flow through the ejector can be considered compressible, turbulent, steady-state and axis- symmetric. The Navier -Stokes continuity, momentum and energy equations give the establishment in CFD recreation of fluid motion. This comes about in Reynolds-averaged Navier- Stokes equations. To discover closure to this, a prevalent approach to turbulence demonstrating utilizes the Boussinesq theory to relate the Reynolds stresses to the mean velocity gradients. The consequent equations are composed in Cartesian tensor form as:

The stress tensor and energy equations are given in equations, separately. The total energy equation takes under consideration the impacts of viscous forces on fluid motion as this joins the viscous dissipation in it.

Ejector Geometry

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_i}(\rho u_i) = 0$$

$$\frac{\partial}{\partial t}(\rho u_i) + \frac{\partial}{\partial x_j}(\rho u_i u_j) = -\frac{\partial p}{\partial x_i} + \frac{\partial \tau_{ij}}{\partial x_j}$$

$$\tau_{ij} = \mu_{eff}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right) - \frac{2}{3}\mu_{eff}\frac{\partial u_k}{\partial x_k}\delta_{ij}$$

$$\frac{\partial}{\partial t}(\rho E) + \frac{\partial}{\partial x_i}(u_i(\rho E + P)) = \vec{\nabla}.\left(\alpha_{eff}\frac{\partial T}{\partial x_i} + u_j(\tau_{ij})\right)$$

I. Ejector Modelling

Ejector, being the foremost basic component directs the in general performance of the ejector refrigeration system. In this way, its configuration and geometry must be carefully decided and designed. Combinations of such measurements and parameters are attempted on within the CFD reenactment one by one until near-optimum geometry is established which gives greatest entrainment ratio at the required working conditions of the refrigeration framework for R141b, R152a and R134a refrigerant. Table gives the procured specifications for the ejector geometry.A common schematic drawing of the ejectors utilized within the numerical recreations. It is accepted that the ejectors are axis-symmetric, in this way as it were the beat half of the drawn ejector will be modeled in this work; there's a line of symmetry on the z-axis.

II. CFD Implementation

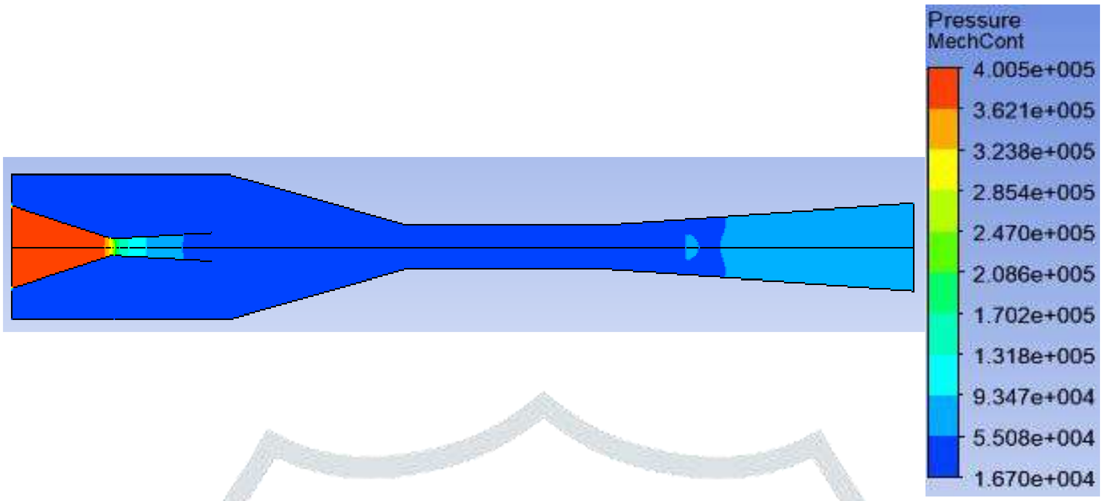
Two-dimensional (2-D) axis- symmetric show of the flow space is utilized to minimize computational time. Quad mesh is employed using Ansys Coinciding due to geometric effortlessness; and is imported to Ansys Fluent v.16.2, for work checking and hence, for the simulation. This makes a difference avoid separating solution and makes the simulation process smooth. In addition, solver chosen is density-based type with certain formulation on the account that the flow is compressible. This type of solver computes the administering equations of continuity, momentum, and energy and species transport at the same time; and afterwards, governing equations for extra scalars such as turbulence will be illuminated consecutively. For steady-state presumption with travelling shocks, implicit detailing may be more effective.

Results And Discussion

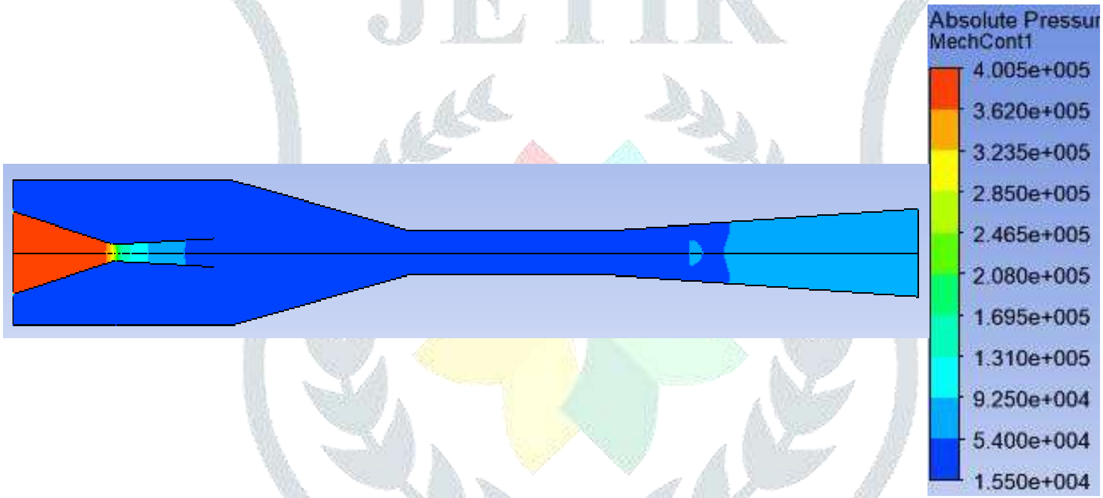
For the given on-design conditions for different refrigerant like R141b, R152a and R134a, the analysis predicts a pressure, density, velocity, temperature. This indicates that the exit state is superheated. The computational domain consists of elements where very few of them fall within the mixture region, as plotted . Similar pattern also happens for ideal gas assumption in other refrigerant. Thus, from a statistical point of view, the flow is basically single phase.

1. Pressure Contours (in Pa)

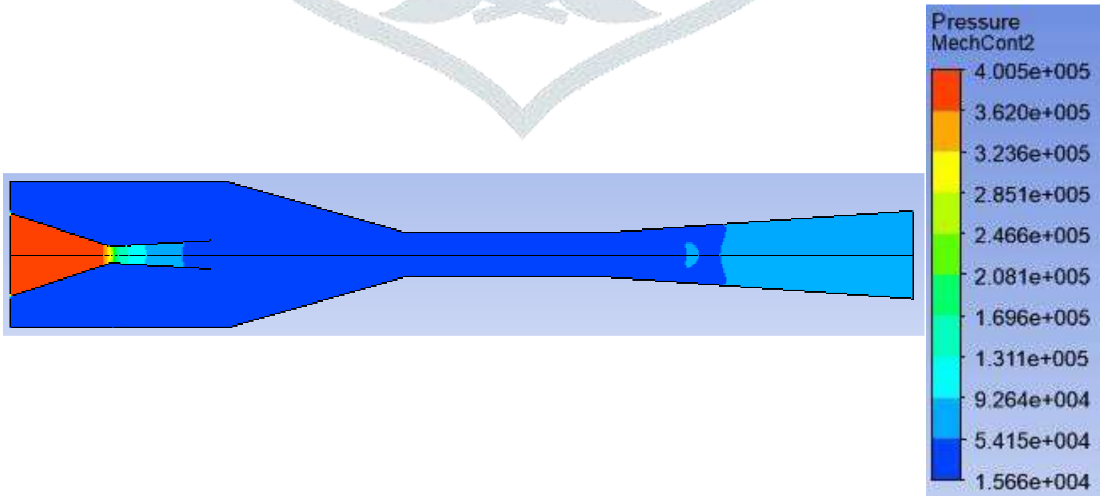
I. Contours of R141b



II. Contours of R152a



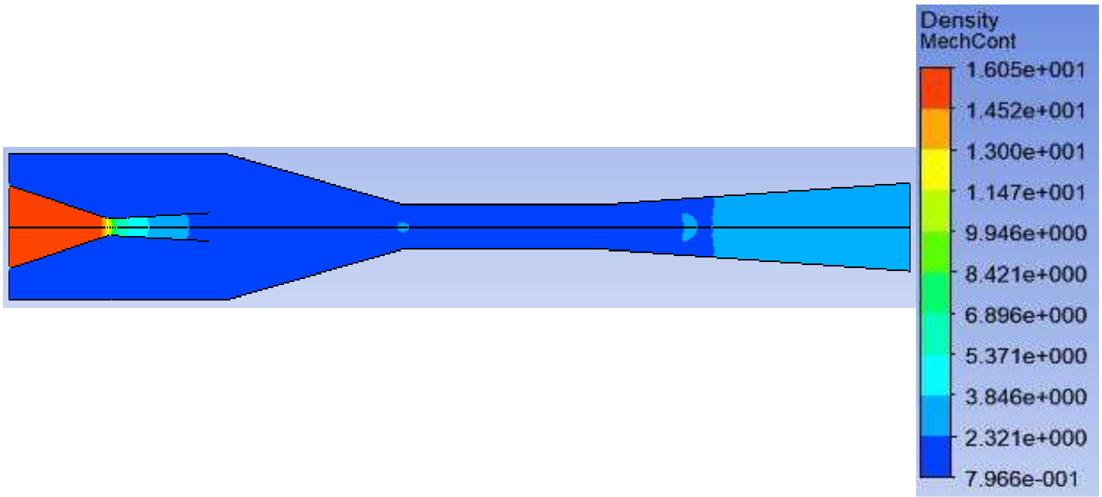
III. Contours of R134a



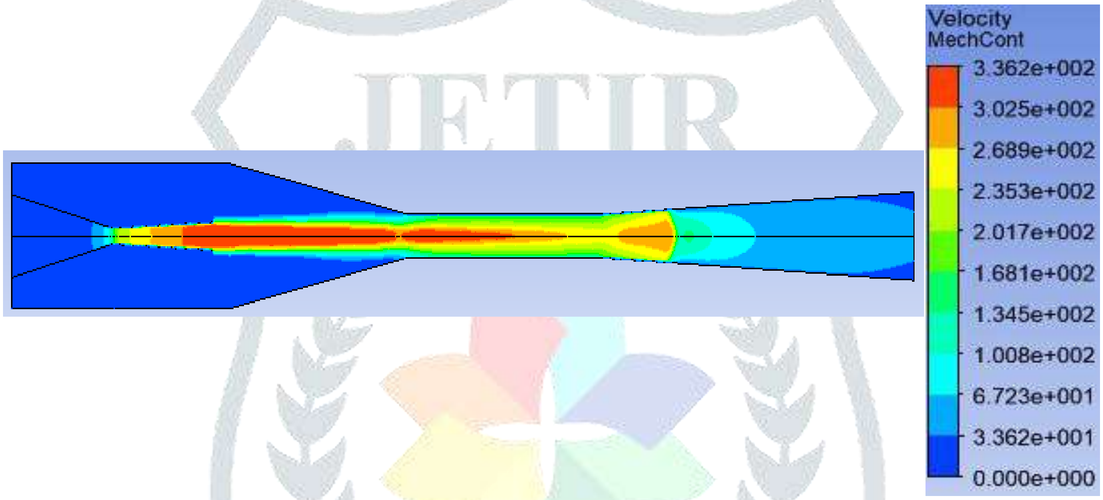
It appears that pressure at inlet nozzle wall is same in all refrigerants 4.005*10^5 and at diffuser maximum is 1.67*10^4 in R141b.So, refrigerant R141b is utilize as application of ejectors in refrigeration system like Vapor Compression Refrigeration System.

2. Density Contours (in kg m^-1)

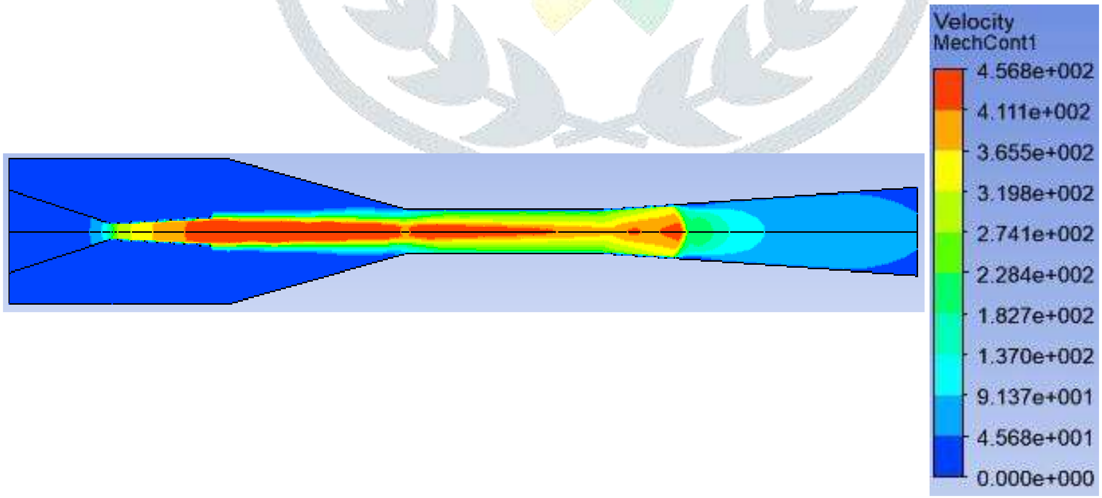
I. Contours of R141b



II. Contours of R152a



III. Contours of R134a



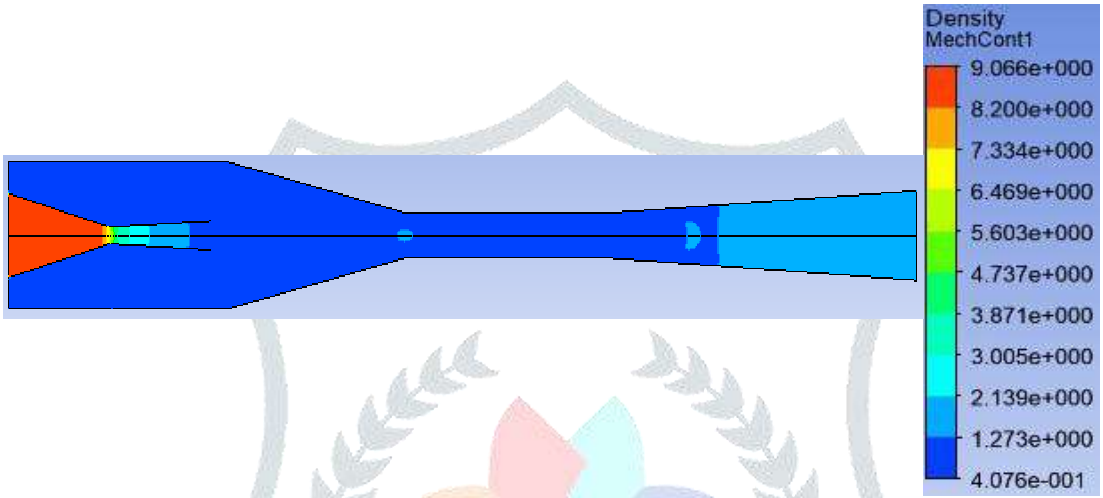
It shows up that density at inlet nozzle wall is greatest 16.05 in R141b refrigerant or least is 9.066 in R152a refrigerant and at diffuser greatest is 0.7966 in R141b refrigerant. So, it is use as application of ejectors in refrigeration system like Ejector Absorber Cycle.

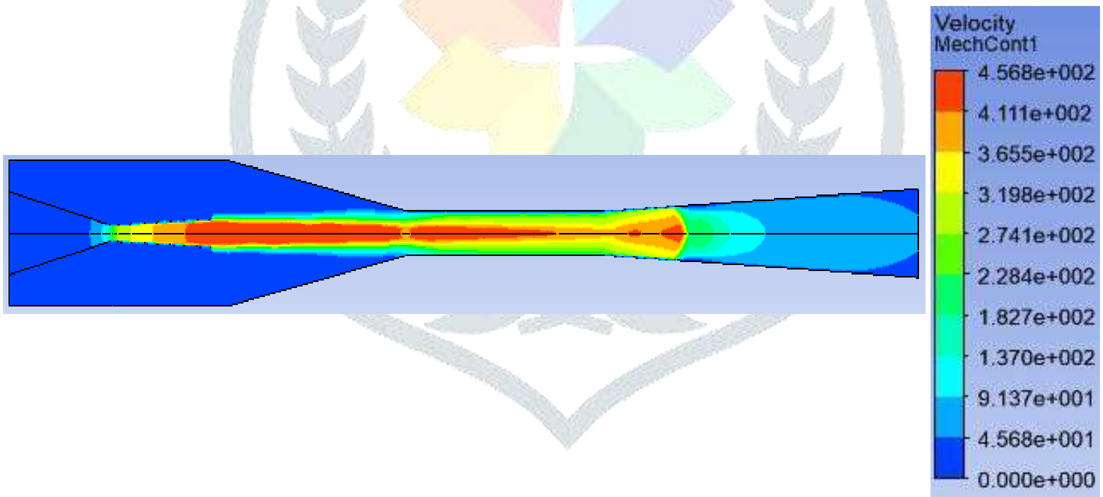
3. Velocity Contours (in m s^-1)

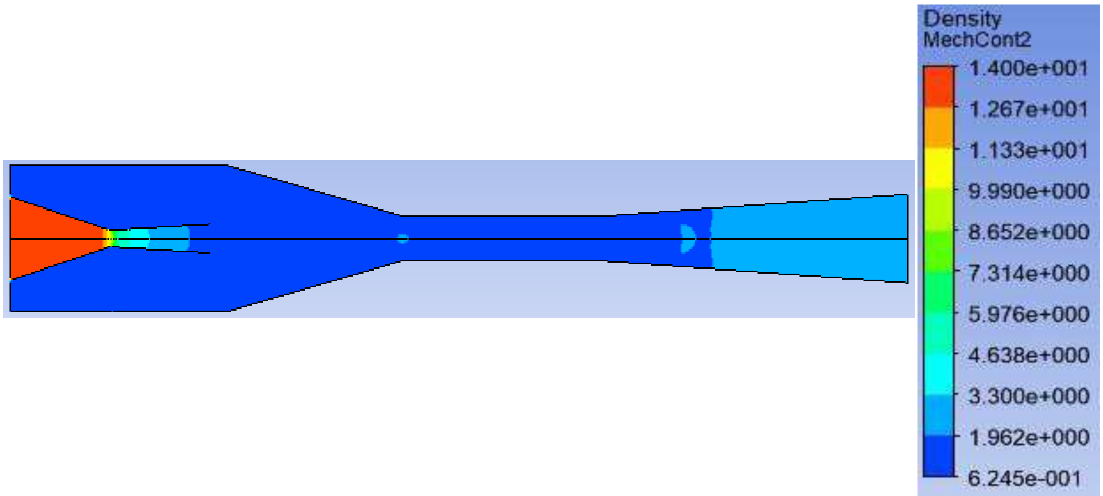
I. Contours of R141b
II. Contours of R152a
III. Contours of R134a

It appears up that velocity at inlet nozzle wall is same in all refrigerants and at between nozzel and diffuser maximum is 4.568*10^2 in R152a refrigerant. So, it is use as ejectors in refrigeration system like Combined Ejector Absorption Cycle and Volumetric Refrigerating Capacity (VRC).

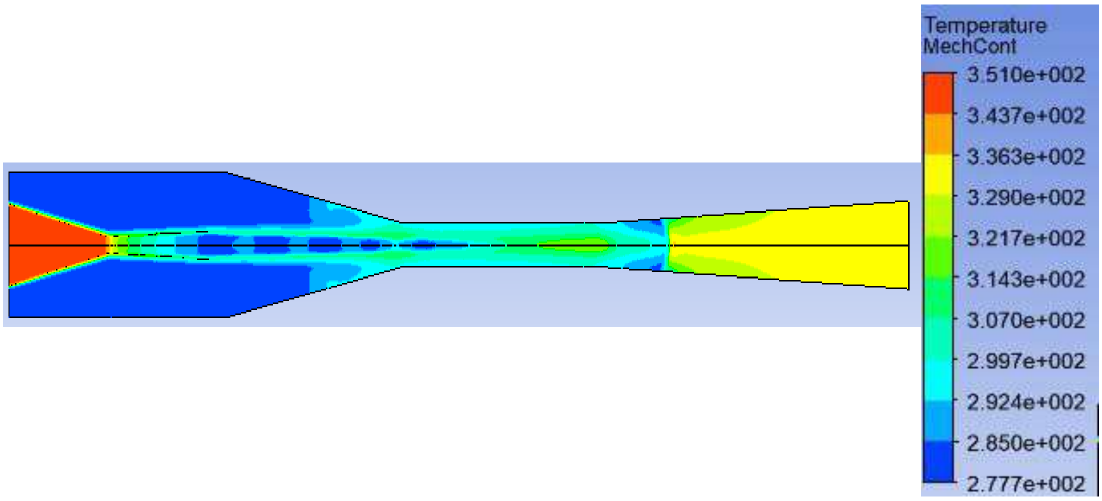
4.Temperature Contours (in K)



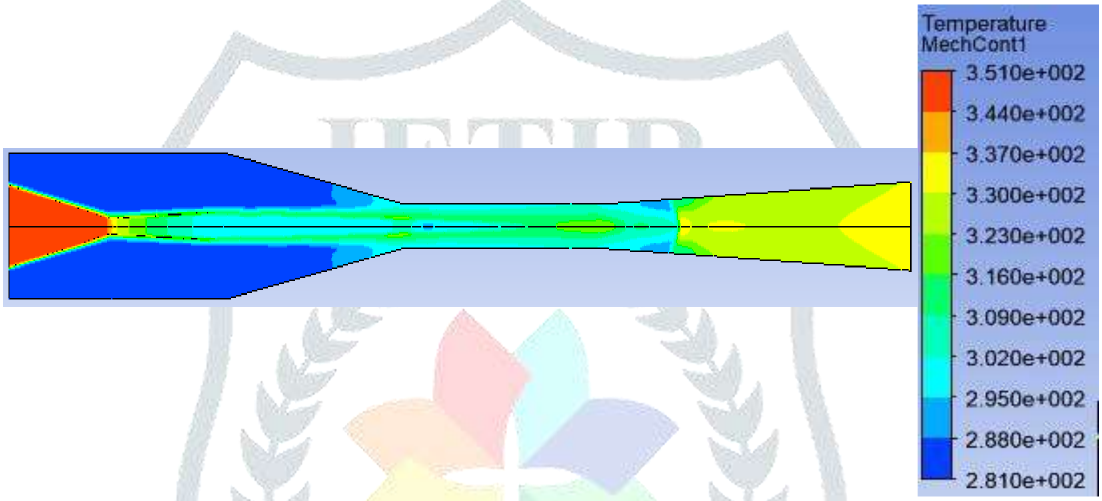




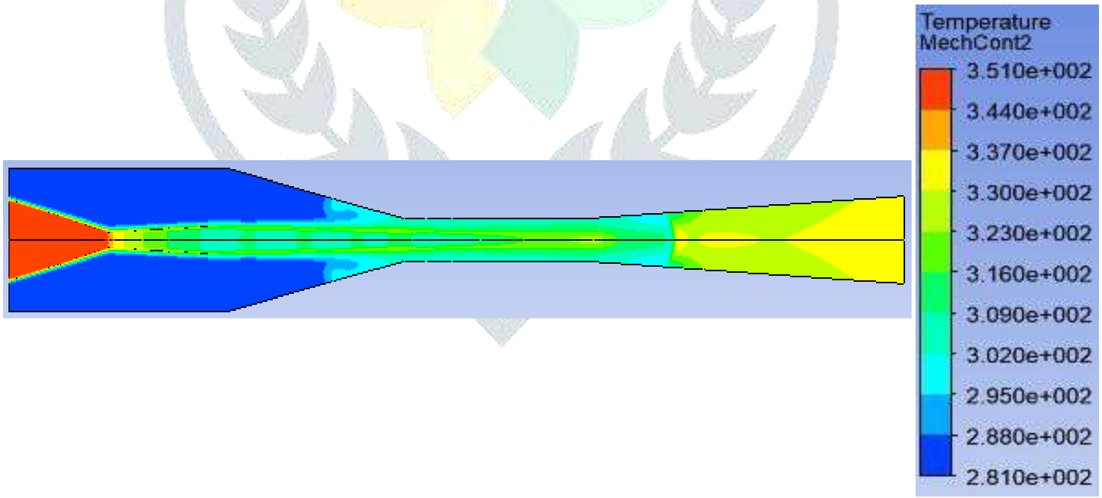
I. Contours of R141b



II. Contours of R152a



III. Contours of R134a



It shows up up that temperature at inlet nozzle wall is same in all refrigerants 3.51*10^2 and at suction chamber maximum is 2.81*10^2 in both R152a or R134a refrigerant or minimum is 2.777*10^2 in R141b refrigerant and at diffuser maximum is 2.88*10^2 in both R152a or R134a refrigerant.So, it is use as ejectors in refrigeration system like Combined Ejector Absorption Cycle.

Conclusion

In this study, at refrigeration operating conditions, there is a corresponding fixed configuration ejector that will operate under optimum conditions. A fixed geometry ejector is determined for given design conditions such as pressure, density, velocity, and temperature that operates on near-optimal ejector operation.Some important conclusions are drawn as follows:

1. R152a are favorable choices for the ejector refrigeration system when the design return temperature of the secondary heating network is 336.3 K.
2. For higher design temperature of the secondary heating network, heat transfer performance of the ejector with R141b is higher than that with other candidate-refrigerants. However, its significant shortcoming is that Ozone Depression Potential is slightly higher than 0. If R141b is managed well in the process of actual application, it would be a better choice for the ejector under the condition of higher design temperature of the secondary heating network.

3. The pressure and temperature contours profile of R152a is very close to the pressure contours of R134a. therefore, R152a will work perfectly as R134a substitute.Refrigerant R152a is more Eco-friendly then R134a.

Future scope

In this present work we have used three different refrigerant for a single ejector design and result in the form of pressure, velocity, temperature, density has been compared after CFD analysis

This work CFD analysis of ejector can be extended by comparing performance of ejector on the basis of

1. Varying or changing the geometric parameter
2. Changing the operating parameter
3. Changing the mesh method

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