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Design and Analysis of Ejector for CO2 Refrigeration

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Abstract: CO_2 refrigeration is in demand all over the world for a variety of issues, including: use of lower GWP refrigerants following the environmental regulations that will direct the operators to adhere to the corporate sustainability norms, and the fact that some western countries have brought their preferred CO_2 refrigeration over the conventional HFC systems. From an environmental point o, traditional hydro- fluorocarbon (HFC) systems used in majority of the refrigeration systems. Numerous lower-GWP alternatives are present that can be used over the full spectrum of GWP ratings, but CO_2 as refrigerant is often considered as a sustainable alternative to the future as it suffices the current and known future regulation requirements. As a result, refrigeration unit manufacturers are devising methods to perfect the CO_2 refrigeration technology to support the use of this environmental friendly alternative. The paper discusses the review of some research work that uses CO_2 as refrigerant, various methods discussed in this work on use of Co2 as refrigerant. The paper discusses the development of CO_2 refrigeration system using the ejector in the refrigeration circuit. The paper deals with the modeling theoretical and structural analysis of the components of ejector. The components of the system have being modeled using unigraphix Nx, and the analysis has being done using Ansys work bench-16.0

Keywords: (HFC) hydro- fluorocarbon, Low GWP refrigerant, Ejector, Design, Analysis.

I. INTRODUCTION

Several methods of using CO_2 as a refrigerant has been explored after discovery of CO_2 as a natural working fluid at the late 19th century, but hardly put in application after the second world war until it was brought in spotlight in the end of the 20th century. CO_2 is recognized as ideal refrigerant environmentally with nearly zero Global Warming Potential (GWP) and having no role in the Ozone Depletion Potential (ODP), in addition to being safe, cheap and compatible with normal refrigeration machine construction methods. The use of R744 refrigeration is experiencing a steady rise in the past few years. The countries with colder climates are seen to use more as compared to the countries with warmer climates owing to the reduced efficiency of the basic CO2 cycle in higher temperature zones when compared to other synthetic HFC refrigerants. When the ambient temperature is high the basic CO2 refrigerating cycle experience a drop in the refrigeration capacity (Q*o*), thus the Coefficient of Performance (COP) of the system is observed to be low. The main challenge is to keep both the outlet enthalpy of gas cooler and the consumption of power to minimum levels. Several technology solutions have being tried in-order that that the system efficiency is maintained even at higher ambient temperatures, Applications of economizers, mechanical sub-coolers, ejectors, expanders, CO2 integrated systems, parallel compression and auxiliary compressors for flash vapour compression and evaporator overfeed etc are few to name.

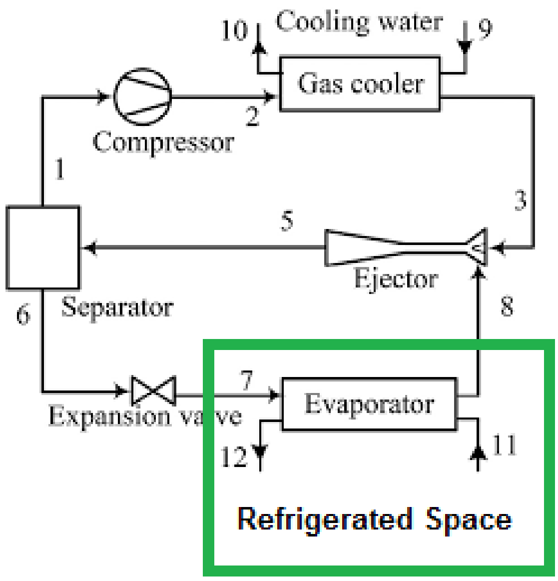

Figure 1 Concept of ejector application in CO2 refrigeration system

The design and analysis of the ejector system was done for the following input data designed for the CO2 refrigeration system:

Temperature of gas cooler outlet (Tgc. out) = 35^{0}C
Temperature of evaporator (Tevap) = 2 ^{0} C
Optimimum pressure at the inlet to the ejector = 8.752 MPa

The specification of the ejector designed are as follows:

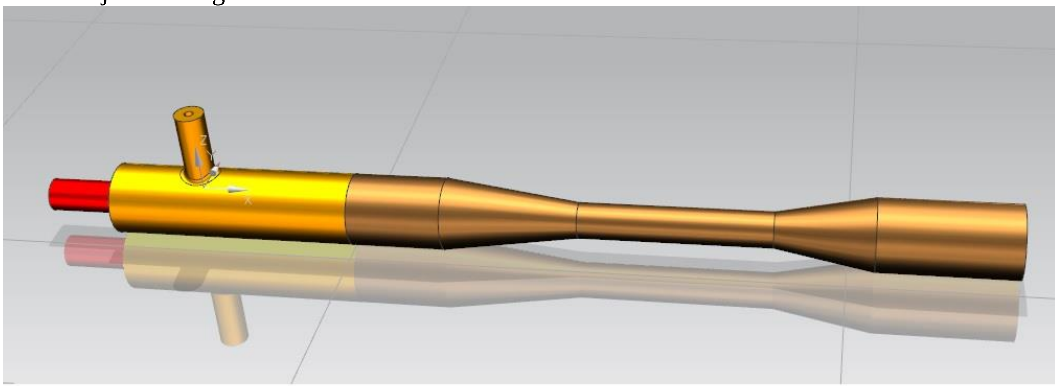

Figure 2 Schematic of ejector

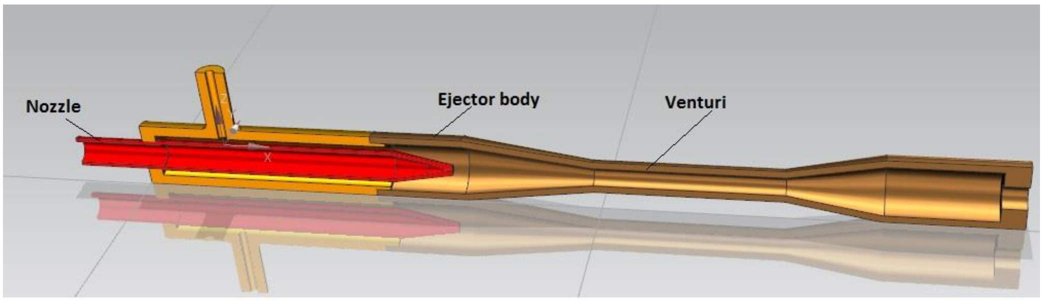

Figure 3 Section vie of the ejector

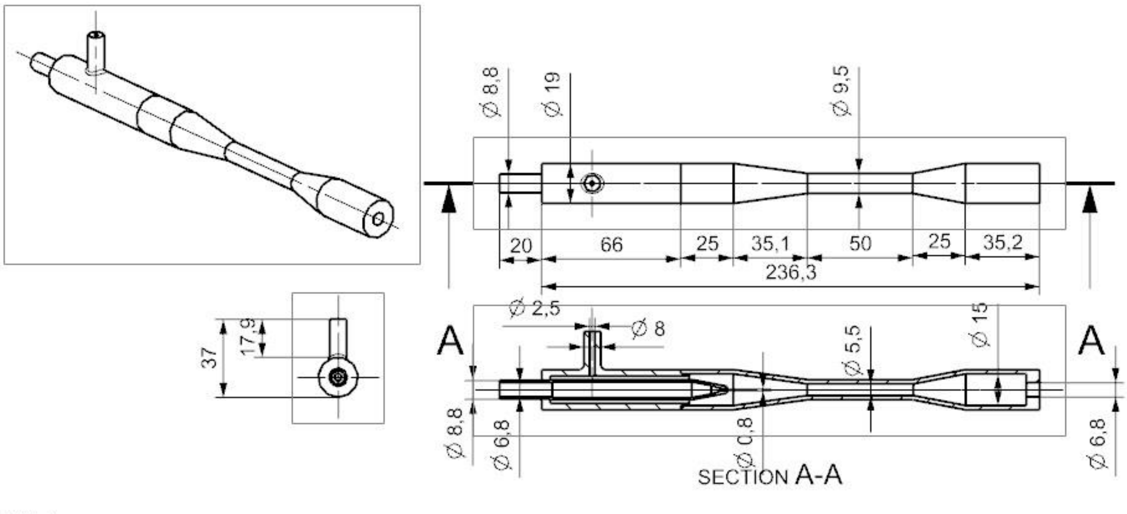

Figure 4 Dimension details of the ejector

II. Design and Analysis of the ejector Nozzle:

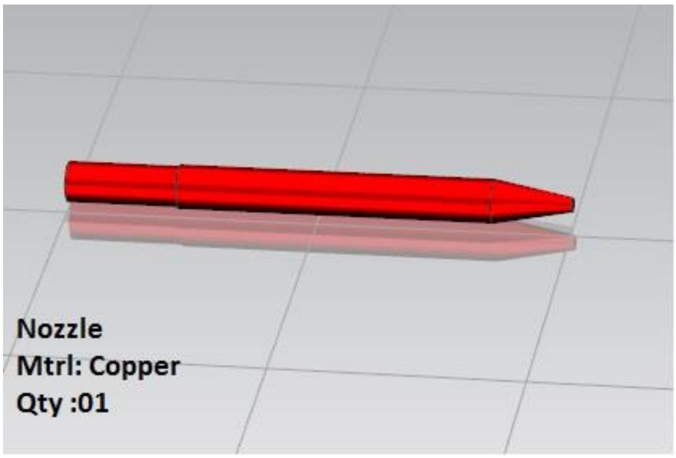

Figure 5 Schematic of ejector nozzle

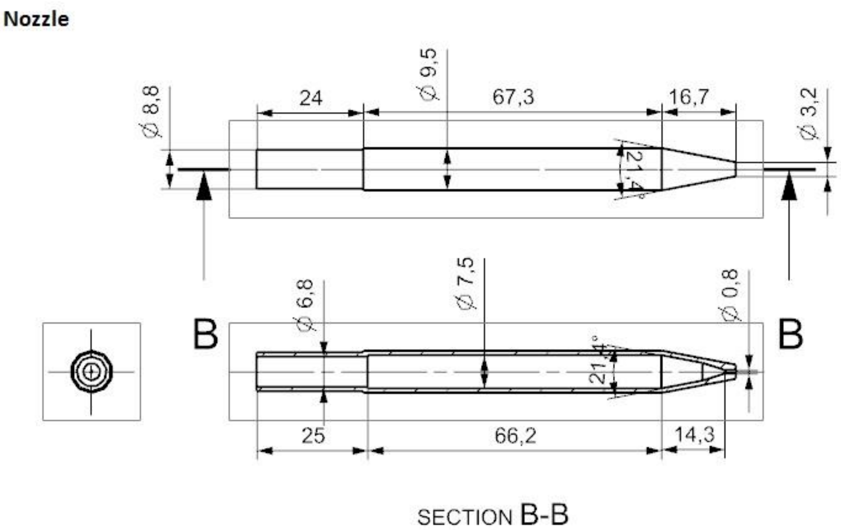

Figure 6 Dimension details of the ejector nozzle

Hoope's stress due to pressure:-Maximum pressure induced in = 8.752 Mpa

$$fc_h = \frac{P \times d}{2t}$$

fc $_{act}$ = 61.26 N/mm^2

As $fc_h < fc_{all}$ Nozzle is safe under Hoope's stress criterion

Boundary conditions for analysis of the ejector Nozzle:

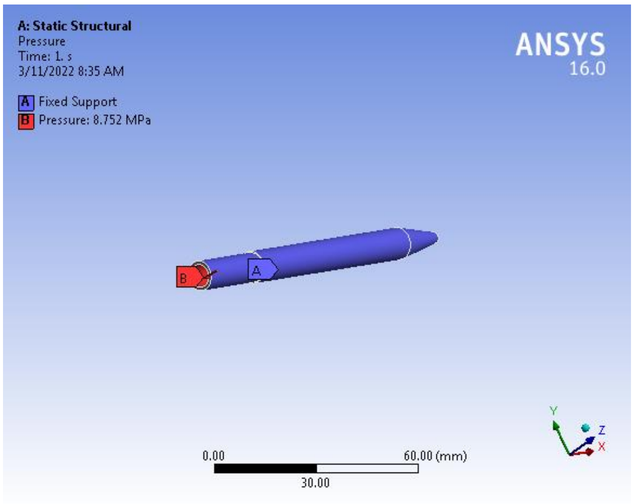

Figure 7 Boundary conditions for structural analysis defined for nozzle

An appropriate physics based boundary condition is must for successful solution of governing equation. In design of nozzle, the problem boundary i.e. inlet boundary pressure. Boundary conditions for tubes are: Pipe inlet pressure: 8.752 MPa

Maximum Stress induced in the Nozzle:

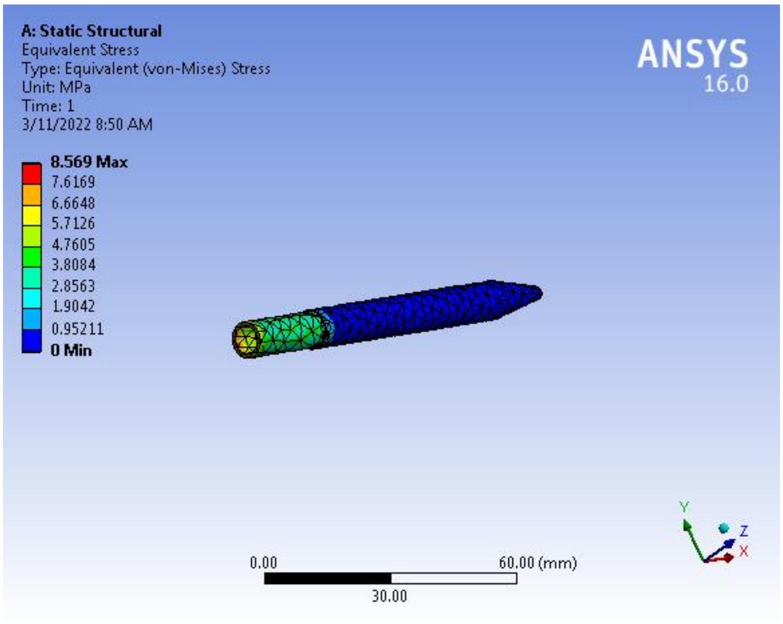

Figure 8 Maximum stress induced in the ejector nozzle

The maximum stress induced in the tube is 8.569 MPa at maximum design pressure of 8.752 MPa which is below the permissible stress of 105 MPa hence the nozzle is safe.

III. Design and Analysis of the ejector Suction chamber:

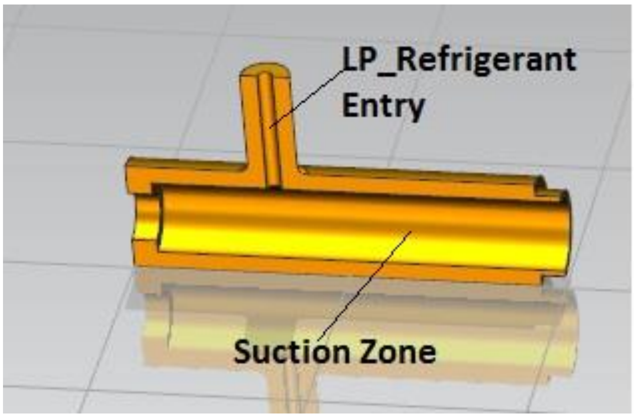

Figure 9 Schematic of the LP refrigerant suction chamber

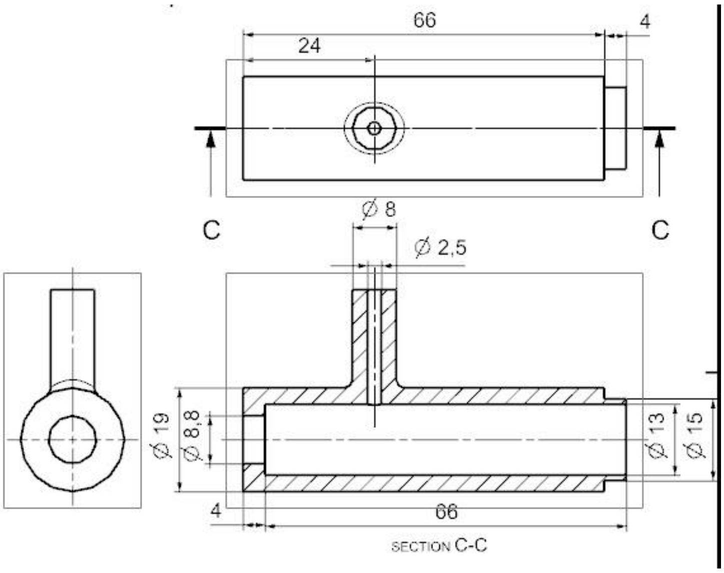

Figure 10 Dimension details of the ejector nozzle

Hoope's stress due to pressure:-Maximum pressure induced in = 8.752 Mpa

$$fc_h = \frac{P \times d}{2t}$$

fc_{act} = 5.63 N/mm^2

As $fc_h < fc_{all}$ Refrigerant Suction chamber is safe under Hoope's stress criterion

Boundary conditions for analysis of the Suction Chamber:

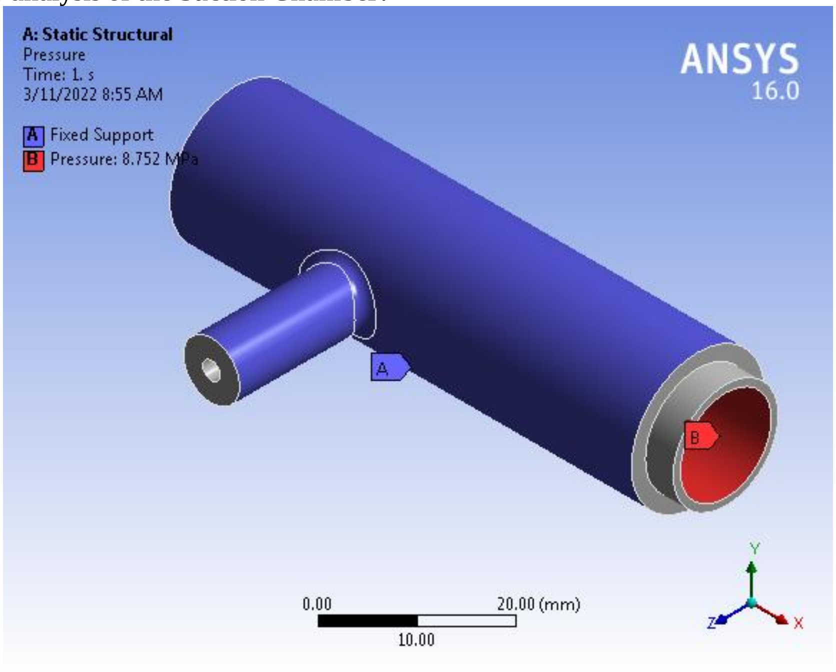

Figure 11 Boundary conditions for structural analysis defined for suction chamber

An appropriate physics based boundary condition is must for successful solution of governing equation. In design of suction chamber, the problem boundary i.e. inlet boundary pressure. Boundary conditions for tubes are: Pipe inlet pressure: 8.752 MPa

Maximum Stress induced in the Suction Chamber:

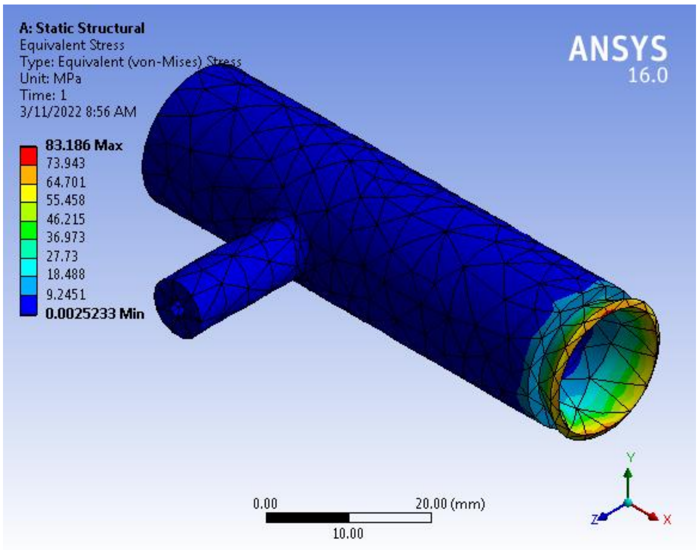

Figure 12 Maximum stress induced in the suction chamber

The maximum stress induced in the tube is 86.186 MPa at maximum design pressure of 8.752 MPa which is below the permissible stress of 105 MPa hence the suction chamber is safe.

IV. Design and Analysis of the ejector diffuser:

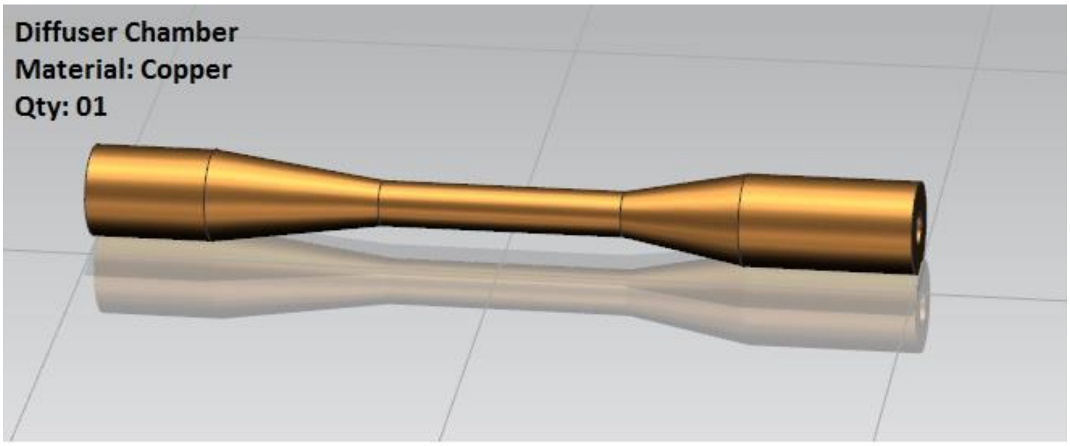

Figure 13 Schematic of the diffuser chamber

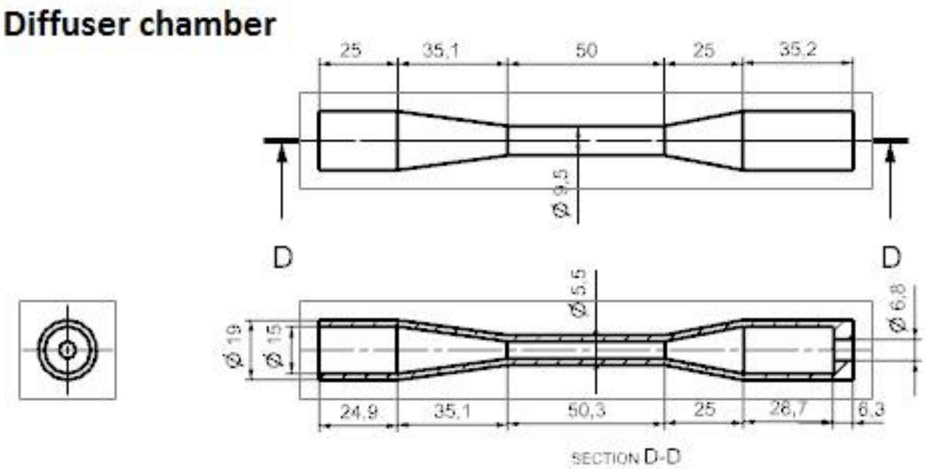

Figure 14 Dimension details of the diffuser chamber

Hoope’s stress due to pressure:-Maximum pressure induced in = 8.752 Mpa

$$fc_h = \frac{P \times d}{2t}$$

fc_{act} = 12.034 N/mm^2

As $fc_h < fc_{all}$ Refrigerant diffuser chamber is safe under Hoope's stress criterion

Boundary conditions for analysis of the diffuser Chamber:

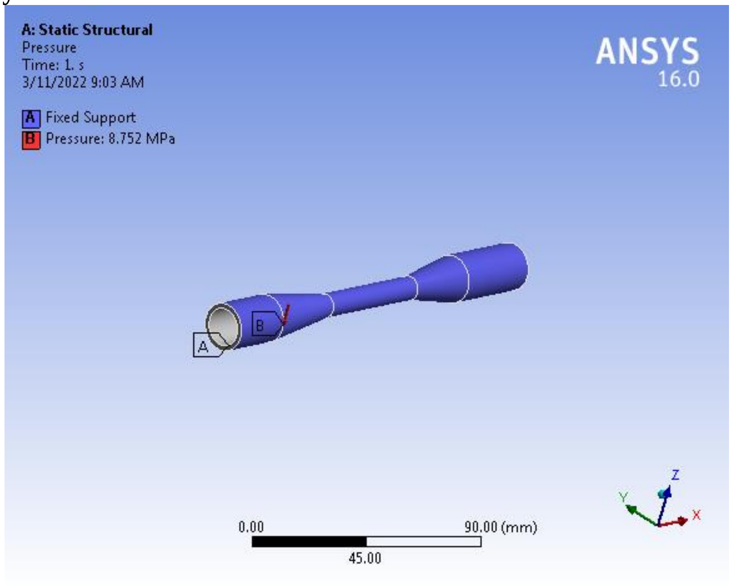

Figure 15 Boundary conditions for structural analysis defined for diffuser chamber

An appropriate physics based boundary condition is must for successful solution of governing equation. In design of diffuser chamber, the problem boundary i.e. inlet boundary pressure . Boundary conditions for tubes are: Pipe inlet pressure: 8.752 MPa

Maximum Stress induced in the Diffuser Chamber:

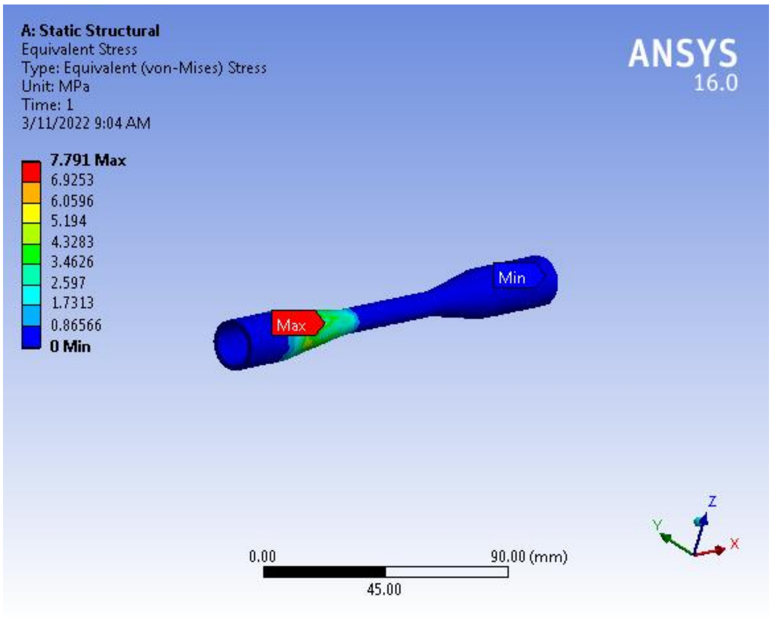

Figure 16 Maximum stress induced in the suction chamber

The maximum stress induced in the tube is 7.791 Mpa at maximum design pressure of 8.752 Mpa which is below the permissible stress of 105 Mpa hence the diffuser chamber is safe.

V. Result and Discussion:

1. The ejector system for CO_2 refrigeration was proposed and the design and analysis is done for system pressure of 8.752 MPa
2. The maximum theoretical stress induced in the nozzle is 61.26 MPa and maximum analytical stress induced in the nozzle is 5.569 MPa at maximum design pressure of 8.752 MPa which is below the permissible stress of 105 MPa hence the nozzle is safe.
3. The maximum theoretical stress induced in the suction chamber is 5.63 MPa and maximum analytical stress induced in the suction chamber is 86.186 MPa at maximum design pressure of 8.752 MPa which is below the permissible stress of 105 MPa hence the nozzle is safe.

4. The maximum theoretical stress induced in the diffuser chamber is 12.034 MPa and maximum analytical stress induced in the diffuser chamber is 7.791 MPa at maximum design pressure of 8.752 MPa which is below the permissible stress of 105 MPa hence the nozzle is safe.

VI. Conclusion:

The paper discusses the development of CO2 refrigeration system using the ejector in the refrigeration circuit. The paper deals with the modeling theoretical and structural analysis of the components of ejector. The components of the system have being modeled using unigraphix Nx, and the analysis has being done using Ansys work bench-16.0. The ejector nozzle, suction chamber and the diffuser chamber have being designed by both theoretical method as well as Ansys analysis and the parts have being found safe by either methods. Future work will include the design of the ejector using CFD analysis and the mass flow rate handled by the ejector will be determined and corresponding reduction in compressor power will be determined and thus the COP of the system will be determined in work to be done.

VII. References

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