Design and Study of effect of number of entries in vortex tube coupled to heat pipe embedded intercooler system

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Abstract

Compressed air gets heated during compression and if the temperature is not brought down the power consumption increases for second stage compression therefore air is needed to be cooled which is conventionally done using air cooling method of intercooler tube type arrangement which requires considerable space, volume and weight. The conventional intercooler does not give sufficient temperature drop; therefore it was thought to investigate another innovative method to transfer the air heat to atmosphere. The vortex tube is a device, having no any moving parts, which produces hot and cold air streams simultaneously at its two ends from a source of compressed air. The project aims at design development fabrication, analysis and testing of the cylindrical heat pipe embedded intercooler and multi entry vortex tube for cooling the flood lubrication system. Which has been modeled using Unigraphix-Nx-8, thermal analysis has been done using Ansys-workbench 16.0. The model of the cylindrical intercooler channel has been tested using a test rig and the results have being plotted. Optimum performance is obtained with multi entry vortex tube with heat pipe embedded intercooler.

Keywords: *Vortex tube, Heat pipe, Inter cooler.*

I INTRODUCTION

Conventionally the flood lubrication system is used for cooling the tool and work interface to attain maximum surface finish, close dimensional tolerance and better tool life. This method has disadvantages that the chips get mixed with the coolant , more over coolant has minimum shelf life and hence has to be replaced frequently and flood lubrication has tendency to wet the workplace area making it dirty slippery and unsafe for working hence the conventional process needs to be replaced by new one which is minimum quantity lubrication. Vortex tube receives the compressed air at 3 to 8 bar pressure and the air is ejected tangentially through a central generator into the spin vortex chamber. This stream of air revolves towards the rear hot end where some escapes through the rear end and the remaining air still spinning, is turned back through the center of this vortex.

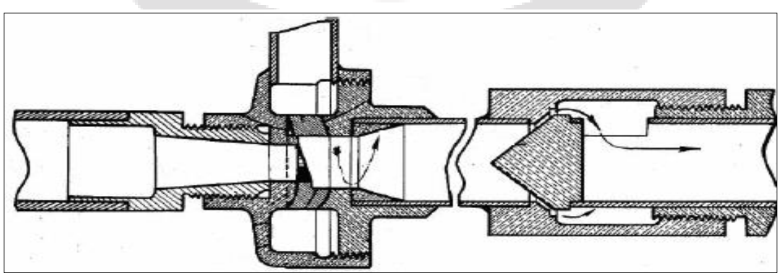

Fig.1 Schematic of vortex tube [1]

The inner air stream gives off kinetic energy in the form of heat to the outer air stream and exits the vortex tube as cooled air**.** The outer stream leaves the opposite end as hot air**.**

The vortex tube is used to cool the air supplied to the MQL system and it will be applied as shown below. The vortex tube will be connected to the mixing chamber of the MQL system and this old air will mix with the lubricating oil and then this cold mixture will be directed towards the cutting area to carry out the cooling of the cutting tool tip.

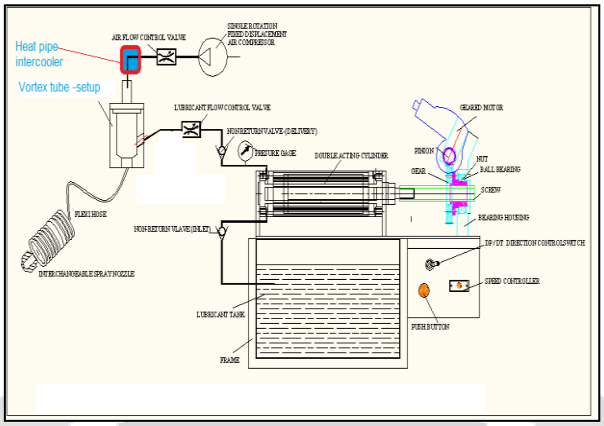

Fig.2 Application of Vortex tube with MQL

Concept of the inter cooler

The intercooler heat exchanger comprises of hollow tube of aluminum that is fitted onto the surface of the heat exchanger through which the hot air is passed. This hollow tube is contact with bent copper fins held onto a helical fin staggered array the arrangement of fins is done such that maximum surface area is achieved in minimum space.

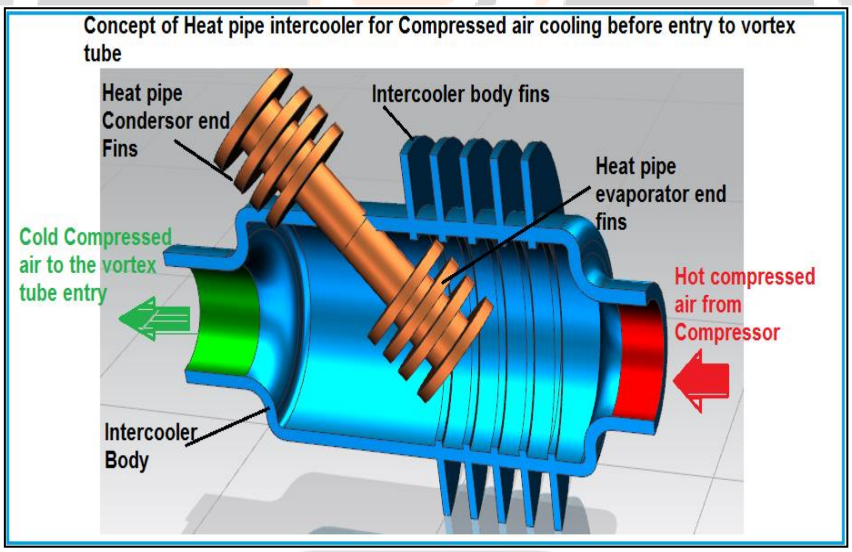

Fig.2 Concept of Intercooler

II OBJECTIVE

1. Design, development andanalysis of Vortex tube.
2. Study the effect of change in number of entry on temperature gradient attainted by vortex tube
3. Design of heat pipe embedded intercooler to reduce the temperature to the vortex tube.
4. Testing of vortex tube with optimal (P, V and T) with and without intercooler
5. Economic analysis of the effect of the effect of application of vortex tube with intercooler on Quantity of Reduced oil volume uses for cooling.

III DESIGN & ANALYSIS

A. Design and analysis of cold end orifice of vortex tube:

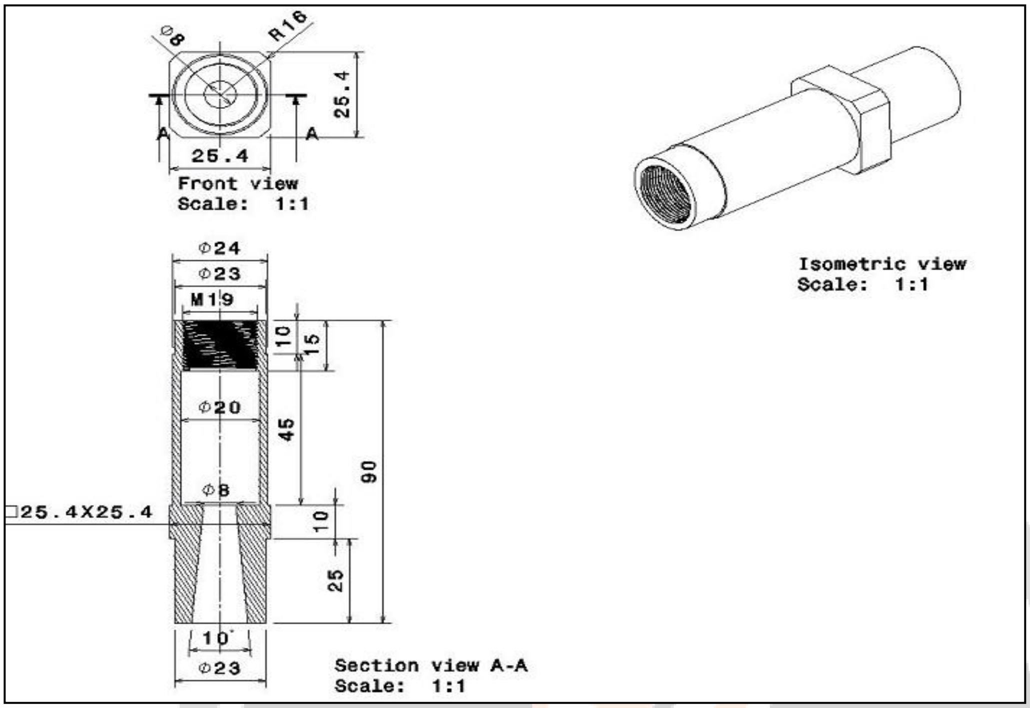

Fig.4 cold end orifice of vortex tube

Hoope's stress due to AIR pressure:-

Maximum pressure induced in the system due to AIR= 6bar

Fch = $pd \div 2t$

Fact = $(0.6\times24) \div (2\times2.25)$

Fact = 3.2 N/mm^2

As fc **h** < fact; part is safe.

Analysis of the Cold end nozzle:

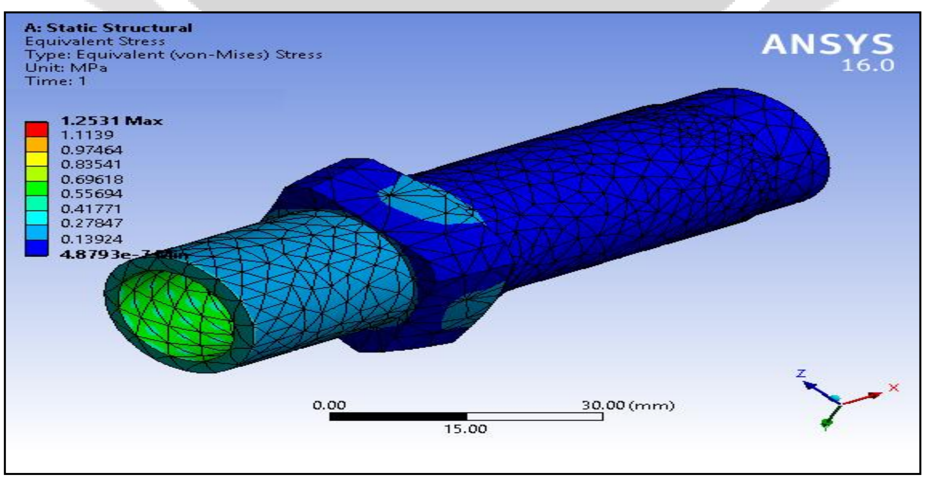

Fig. 5 Analysis cold end orifice of vortex tube

The maximum Von-misses stresses in the part are 1.25 MPa which is far below the allowable value 32 MPa hence the part is safe under given loading conditions.

B. Design of Twin Nozzle

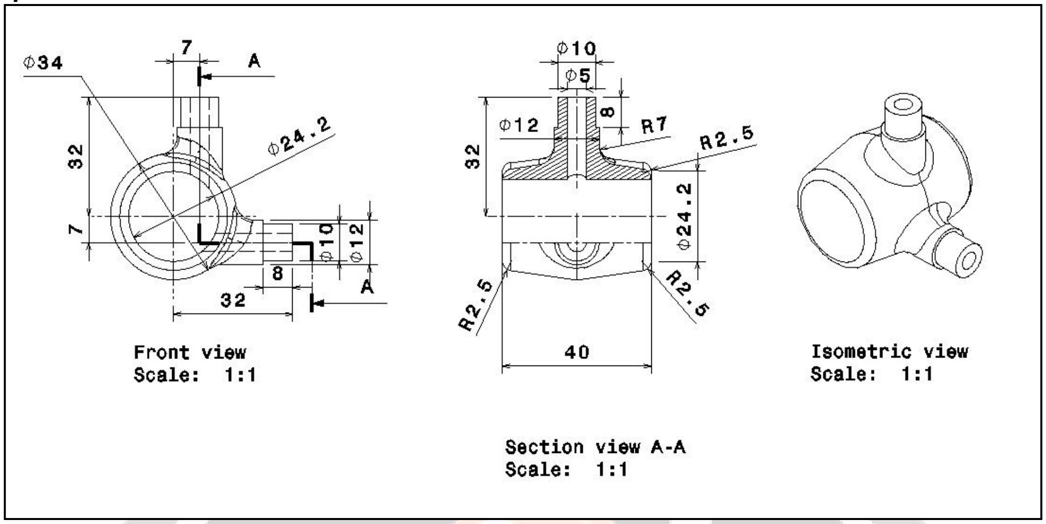

Fig.6 Design of Twin Nozzle

Hoope's stress due to AIR pressure:-

Maximum pressure induced in the system due to AIR= 6bar

$Fc_h = pd \div 2t$

Fact = (0.6×24) ÷(2×2.25)

Fact = 3.2 N/mm^2

As fc_h < fact ; inlet nozzle is safe.

Analysis of the twin nozzle:

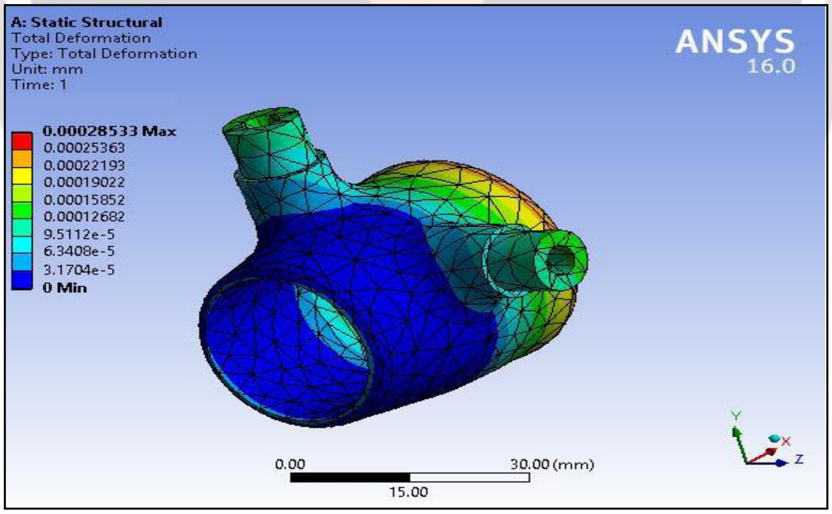

Fig.7 Total Deformation of Twin Nozzle

The above figure gives the maximum possible deformation for a given conditions which is 0.00028533mm.

IV TEST AND TRIAL

The test rig prepared for the testing of the vortex tube and intercooler combination is as below

A. ***Experimental setup***

Fig.8 Experimental setup

V. RESULT & DISCUSSION

A. Test and Trial on vortex tube:-

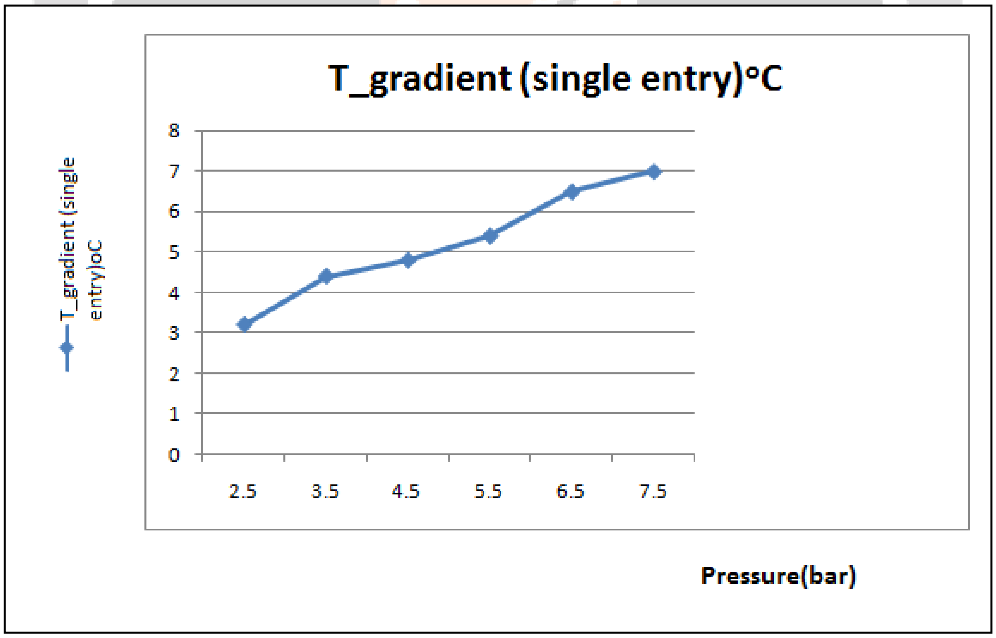

Fig.9 Temperature Gradient °C Vs Pressure (bar) of single entry vortex tube

These experimental data for a counter flow type vortex tube with L/D=20.5 have been tested by using the compressed air with single and double entry nozzle under the processing conditions of 3 to 8 bar operating pressure. Graph 9 shows the performance of vortex tube with single entry inlet nozzle, that the temperature gradient is increases with increase in the inlet pressure to the vortex tube.

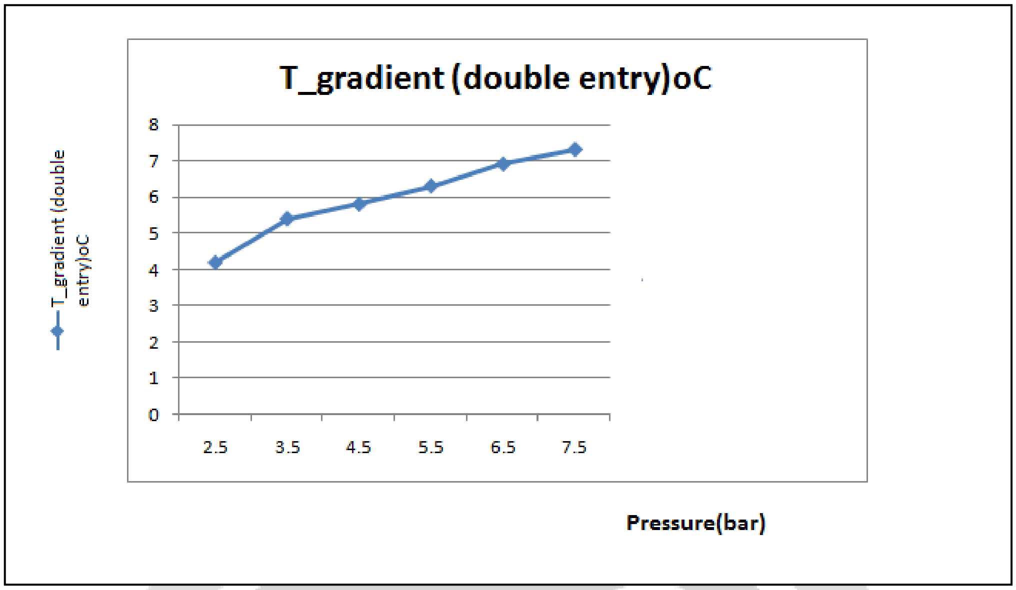

Fig. 10 Temperature Gradient °C Vs Pressure (bar) of double entry vortex tube

Above graph shows that the temperature gradient is seen to increase with the increase in the inlet pressure to the vortex tube for the double entry inlet nozzle also, it indicates that in both cases as inlet pressure increases vortex tube gives batter temperature separation.

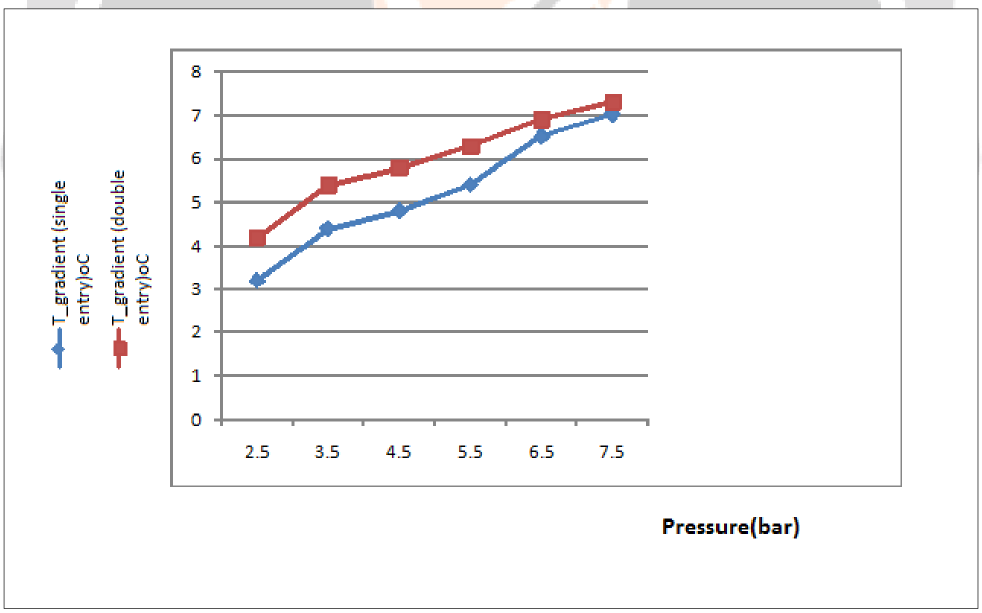

Fig.11 Comparison Graph of Single and Double Entry vortex tube

the above graph conclude that the temperature gradient is seen to increase with the increase in the inlet pressure to the vortex tube in both cases of single entry nozzle and double try nozzle, but the temperature gradient of the double entry is better than that of the single entry hence the double entry vortex tube shows better performance

B. Test and Trial on Intercooler

Special type of intercooler arrangement is developed to investigates the effect of temperature before the vortex tube, It is also necessary to mentioned that the design intercooler is tested with or

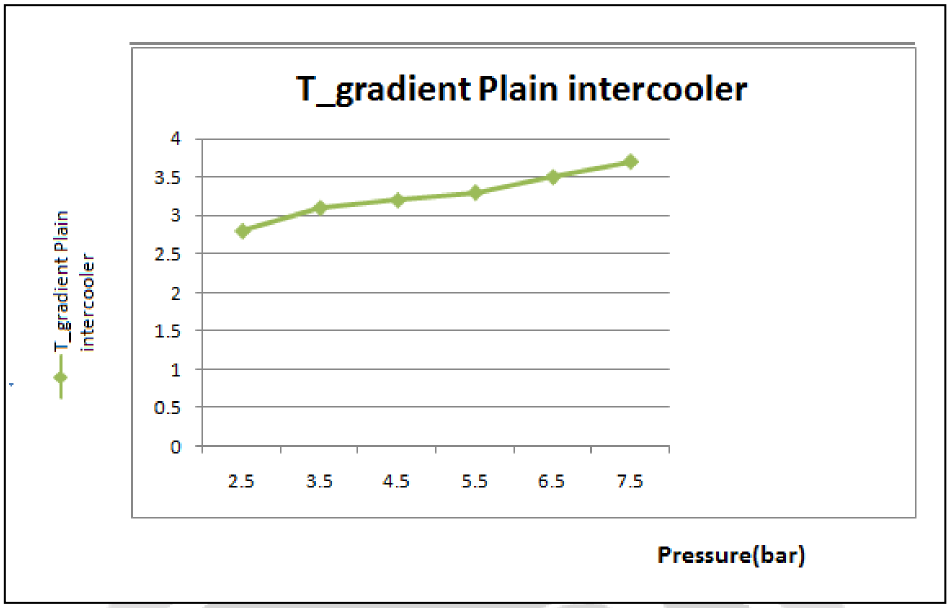

Fig.12 Temperature Gradient °C Vs Pressure (bar) for plain intercooler

Without heat pipe, graph 12 shows that the performance of vortex tube is seen to increase with the increase in the inlet pressure by applying plain intercooler with no heat pipe.

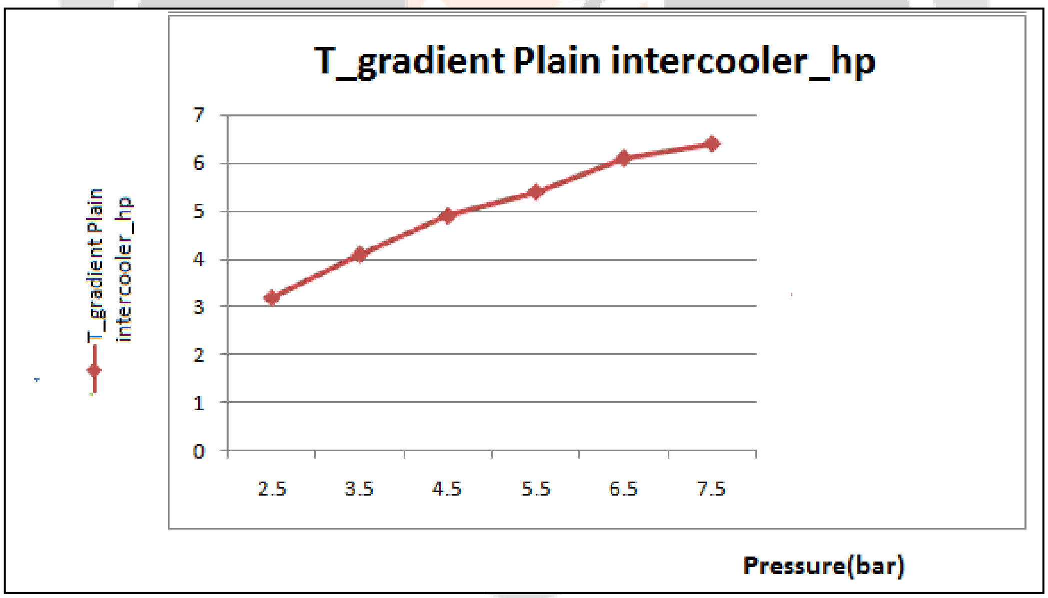

Fig.13 Temperature Gradient °C Vs Pressure (bar) for intercooler with heat pipe

The temperature gradient is seen to increase with the increase in the inlet pressure to the vortex tube by applying the intercooler with heat pipe.

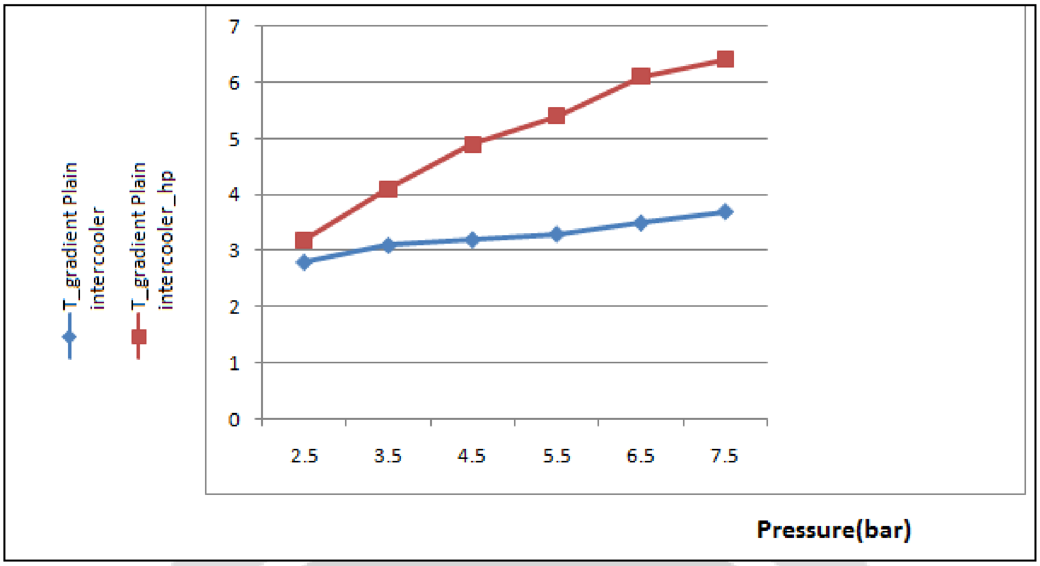

Fig.14 Temperature Gradient °C Vs Pressure for intercooler (Without HP / With HP)

The temperature gradient is seen to increase with the increase in the inlet pressure to the intercooler in both cases but the temperature gradient of the heat pipe intercooler is better than that of the plain intercooler hence the heat pipe intercooler shows better performance

VI. RESULT AND DISCUSSION

1. The temperature gradient is seen to increase with the increase in the inlet pressure to the vortex tube in both cases but the temperature gradient of the double entry is better than that of the single entry hence the double entry vortex tube shows better performance

2. The temperature gradient is seen to increase with the increase in the inlet pressure to the intercooler in both cases but the temperature gradient of the heat pipe intercooler is better than that of the plain intercooler hence the heat pipe intercooler shows better performance

3. The theoretical and analytical design of the vortex tube cold end nozzle shows that the stress is well below the permissible limit and the part is safe.

VII. CONCLUSION

The sizing, design analysis critical components of heat pipe intercooler with vortex tube is successfully done and the dimensions of the components have being determined. Estimation of the maximum stress induced in the components of the system have being determined by both theoretical method as well as using Ansys Work bench and the results indicate that the maximum stress values are well below the permissible limit hence the parts are safe under given system of loads. .The test and trial was conducted and The temperature gradient is seen to increase with the increase in the inlet pressure to the vortex tube in both cases but the temperature gradient of the double entry is better than that of the single entry hence the double entry vortex tube shows better performance The temperature gradient is seen to increase with the increase in the inlet pressure to the intercooler in both cases but the temperature gradient of the heat pipe intercooler is better than that of the plain intercooler hence the heat pipe intercooler shows better performance .

VIII. NOMENCLATURE

Symbol	variable	Unit
L	Length of vortex tube	Mm
D	Diameter of vortex tube	Mm
L/D	Length to Diameter ratio	-
d_c	Orifice diameter	Mm
N	Number of nozzle	-
T_C	Cold end temperature	°C
T_h	Hot end temperature	°C
T_{in}	Inlet temperature	°C
ΔT	Temperature Difference	°C

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