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Design Analysis and performance evaluation of Heat pipe-based intercooler for compressed air cooling in multistage compressor.

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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 or the temperature of the air needs to be brought down. Air is therefore needed as 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, thus there is a need of another innovative method to transfer the air heat to atmosphere. The Intercooler heat exchanger consists of a hollow tube of aluminum that is fitted onto the surface of the heat exchanger through which the hot air is passed. This heat pipe is in contact with copper heat pipe with ethanol methanol mixture as the working fluid the arrangement of fins is done such that maximum surface area is achieved in minimum space. The paper aims at design development analysis of the casing pipe and thermal design of the fins used in the Intercooler for cooling. The parts are modeled using Unigraphix-Nx-8, thermal analysis will be done using Ansys-workbench 16.0. The testing of the cylindrical Intercooler channel has been done using a test rig to determine the total temperature gradient at various pressure and flow rates.**

INTRODUCTION

Intercooler are devices that mainly used to reduce the temperature of the compressed air which reduce its volume, so the work done by the compressor will be less for less volume which will reduce the input power in case of multi-sage compression. Hence, the efficiency of compressor is increased. Although the present method used is as shown below

Fig 1.1: Micro-channel heat exchangers

Micro-channel heat exchangers are used which require a fan assistance for operation, secondly a very high in cost and thirdly considerable amount of pressure drop is seen in the case of micro-channel heat exchanger based Intercooler, hence effective low cost, compact and easy to install device with the least pressure drop is needed to solve the above problem.

I. DESIGN& ANALYSIS

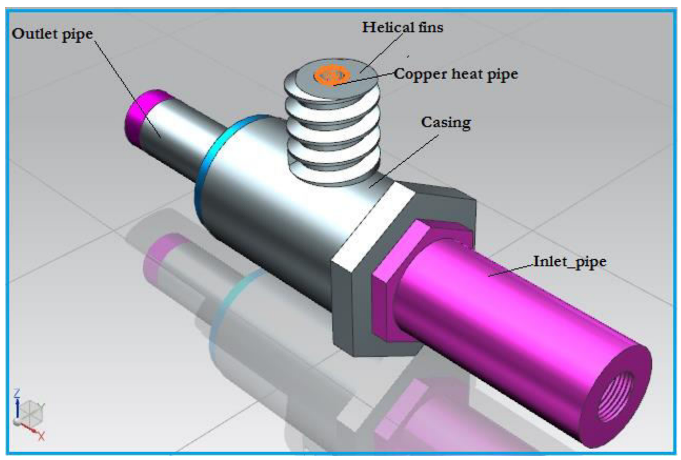


Fig 1.1: Cad Design

The heat pipe-based intercooler arrangement is as shown above where in the heat pipe carries helical at both evaporator and condenser end, and it is mounted in an aluminum casing. Owing to the latent heat dissipation possible with the heat pipe the intercooler proves to be effective, compact and low cost as compared to the conventional micro channel intercooler moreover no fan is needed.

Heat pipe specification:

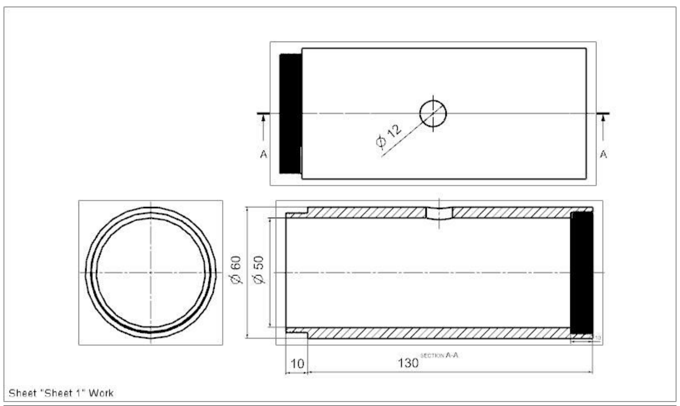
MAXIMUM WATTS AT DIFFERENT TEMPRATURE

DIAMETER	200C	300C
12 mm	100 WATT	126 watt

1. The power handling figures are for heat pipe working in horizontal position.
2. Diameter: 12mm
3. Length 50 mm long
4. evaporator length 18mm
5. condenser length 18mm
6. adiabatic length =14 mm
7. Copper wire mesh
8. Working fluid (ethanol methanol 60:40)

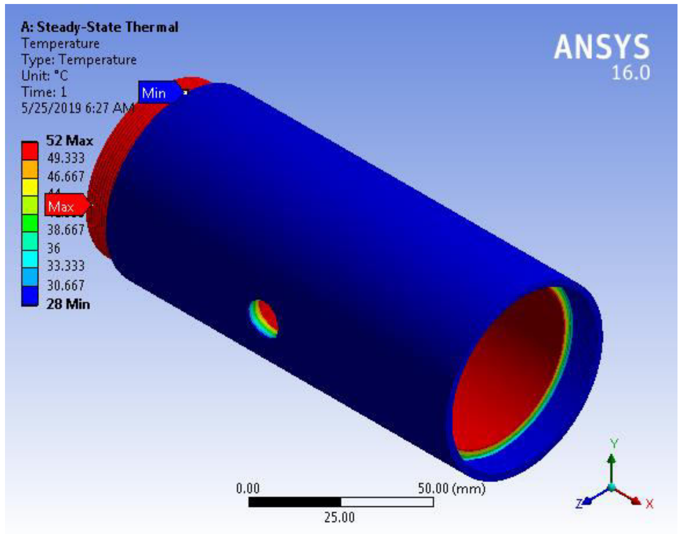
Design & Analysis of Casing pipe:

Material : Aluminium.

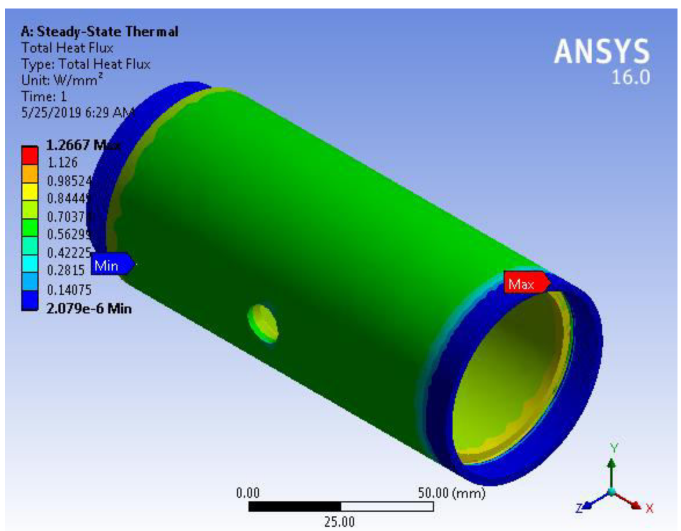


Hoope's stress due to oil pressure:-Maximum pressure induced in system due to oil =10bar= 1 Mpa ,
using fpact = Pxd /2t
⇒fpact = 18.75N/mm2As fpact< fc all ; (allowable stress 60 Mpa) casing pipe is safe
The maximum Von-mises stress is 4.0025 Mpa

Thermal Analsysis of casing:

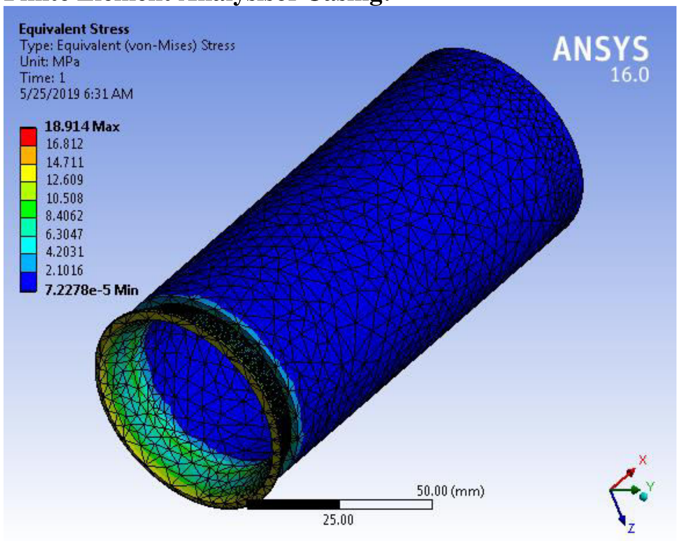


The figure shows the temperature distribution inside the casing where in the inside surfaceis in contact with hot air is at 52 ^{o}C and the outside surface expeosed to atmospheric air is at 28 ^{o}C

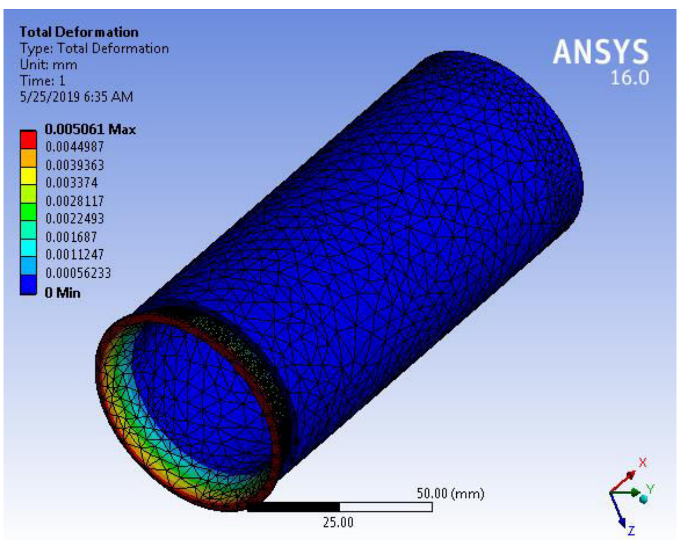


The maximum heat flux through the casing is 1.27 watt/mm2 and thereby it is observed that the casing also contributes partially to the heat dissipation and cooling of the air.
Structural Analysis as a coupling

Finite Element Analysisof Casing:



The result above are combination of the mechanical stresses induced owing to the thermal stress and additional stress due to pressure of 10 bar inside the casing, the maximum stress induced is 18.91 Mpa which is below the allowable value of 60 Mpa , so the casing is safe.



The maximum deformation seen is 0.005 mm which is negligible hence the casing is safe

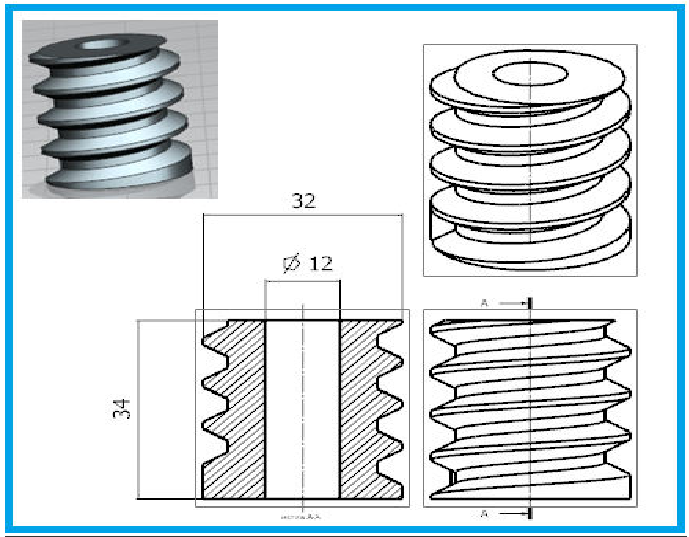
Result & discussion:

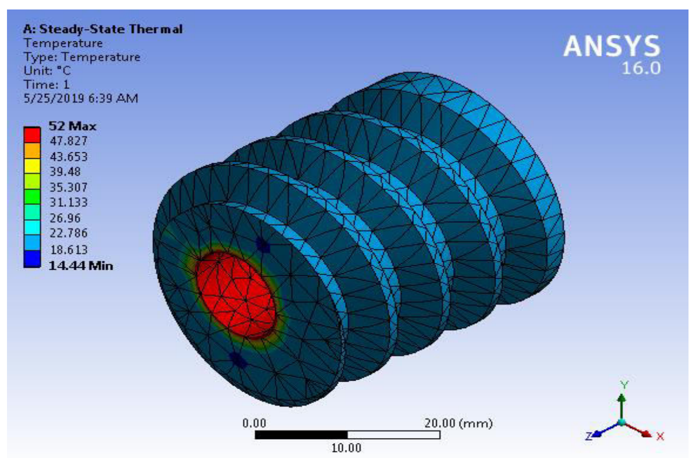
Part Name	Heat flux Watt/mm2	Maximum theoretical stress (MPa)	Von-mises stress (MPa)	Maximum deformation mm	Result
Inlet Pipe	1.256	18	18.91	0.005	safe

1. Maximum stress by theoretical method and Von-mises stress are well below the allowable limit, hence the casing pipe is safe.
2. Casing pipe shows negligible deformation under the action of system of forces
3. Maximum heat flux through the casing 1.256 watt/mm2

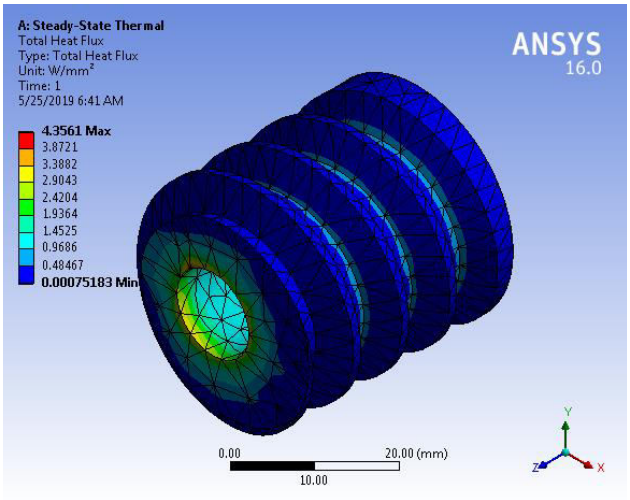
Analysis of Fins

Material: Aluminum.





The figure shows the temperature distribution inside the fin where in the inside surface is in contact with hot air is at 52°C and the outside surface exposed to atmospheric air is at 28 °C



The maximum heat flux through the casing is 4.356 watt/mm2 and thereby it is observed that the fins contributes significantly to the heat dissipation and cooling of the air.

II. TESTING & TRIAL OF INTERCOOLER FOR MULTISTAGE COMPRESSOR

OBJECTIVES OF TESTING:

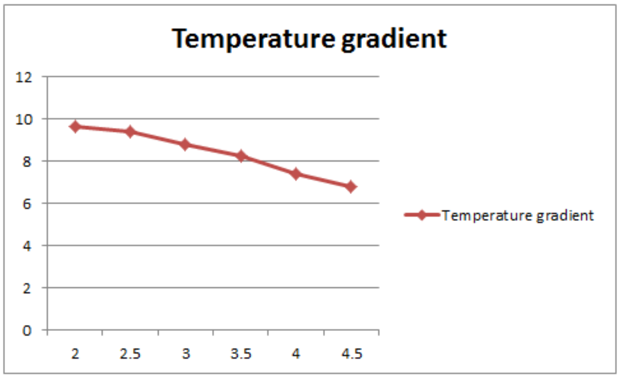
Testing of the hydraulic noise suppressor for following characteristics

a) Temperature gradient across the intercooler at different inlet pressure conditions
b) Heat dissipated by the intercooler at different pressure conditions

PROCEDURE OF TRIAL: (Constant flow rate. variable pressure)

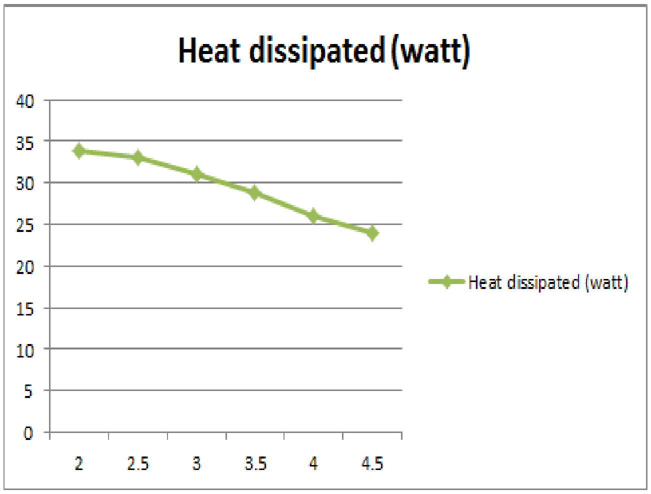
1. Start the compressor and set the flow rate to 3 cfm
2. Set pressure to 2 bar
3. Note temperature at inlet
4. Note temperature at outlet
5. Repeat procedure for different pressure settings

Sr no.	Flow (cfm)	Inlet Pressure Bar	Inlet Temperature °C	Outlet Temperature °C	Temperature Gradient °C	Heat dissipated watt
01	3	2	48	38.4	9.6	33.86448
02	3	2.5	48	38.6	9.4	33.15897
03	3	3	48	39.2	8.8	31.04244
04	3	3.5	48	39.8	8.2	28.92591
05	3	4.0	48	40.6	7.4	26.10387
06	3	4.5	48	41.2	6.8	23.98734



Pressure (bar)

The temperature gradient is seen to decrease with the increase in the pressure, this is owing to the fact that at higher pressure work done on air is more.



Pressure (bar)

The heat dissipated through the intercooler is seen to decrease with the increase in the pressure, this is owing to the fact that at higher pressure work done on air is more.

III. CONCLUSION

1. The design of the casing pipe shows that the maximum stress induced calculated using theoretical method as well as the analytical method is well below the allowable stress in the material of the part and hence it is safe, so also deformation is negligible, and the maximum heat flux is 1.256 watt /mm2
2. The design of the fins shows that the maximum heat flux is 4.356 watt /mm2 and that the fins contribute significantly to the heat dissipation
3. Testing revealed that the temperature gradient is seen to decrease with the increase in the pressure, this is owing to the fact that at higher pressure work done on air is more.
4. The heat dissipated through the Intercooler is seen to decrease with the increase in the pressure, this is owing to the fact that at higher pressure work done on air is more.

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