Impact Factor (SJIF): 5.301

International Journal of Advance Research in Engineering, Science & Technology

e-ISSN: 2393-9877, p-ISSN: 2394-2444
Volume 5, Issue 7, July-2018

Optimization of Shell –And -Tube Intercooler in Multistage Compressor System Using CFD Analysis

N RAJENDRA[1], B PRASAD REDDY (Asst.Proffesor)[2], Y SATYANARAYANA (Asst.Proffesor)[3]
KAKINADA INSTITUTE OF TECHONOLOGY AND SCIENCE

Abstract

Multi-staging with intercoolers is an efficient technique for reducing the mandatory energy to drive gas compressors. Increase of efficiency may end up in large energy savings for larger compressor systems. Optimization of the intercooler is very desirable because the size of compressor system will increase.

In this thesis, analytical investigations are done on the shell and tube intercooler without and with 140^0 baffles and optimized for better heat transfer rate. The analysis is performed using forced convective heat transfer to determine flow characteristics of air flowing under turbulent flow conditions. 3D models of the intercooler without and with baffles are done in Creo 2.0.

Thermal and CFD analysis is done on the intercooler. CFD analysis is done under different boundary conditions. The materials considered for shell and tube intercooler are Aluminum, Titanium and Copper for thermal analysis and compared for better material. The input of heat transfer coefficient for thermal analysis is taken from output of CFD analysis.

Keywords: Intercooler, Shell and Tube and CFD analysis.

Introduction

An intercooler is a mechanical device to cool a fluid, as well as liquids or gases, between stages of a multi-stage compression method, generally a heat exchanger that removes waste heat in a gas compressor. They're employed in several applications, as well as air compressors, air conditioners, refrigerators, and gas turbines, and are wide better-known in automotive use as an air-to-air or air-to-liquid cooler for forced induction (turbocharged or supercharged) IC engines to boost their volumetrically efficiency by increasing intake air charge density through nearly isobaric (constant pressure) cooling.

Air compressors are utilized in different industries to provide process requirements, operate pneumatic tools and equipment’s, and meet instrumentation desires. Compressed gas systems use 10% of the whole industrial energy use within the world. Also, these systems are usually one in all the most expensive utilities in an industrial facility

The extent to that this will be accomplished by economic concerns. A second (and additional practical) method of reducing compressor work is to keep the specific volume of the gas as little as attainable throughout the compression method. This can be done by maintaining the temperature of the gas as low as attainable at the inlet of compressor and through compression since the specific volume of a gas is proportional to temperature.

1.Inter cooler Types:

In general, the intercooler can be divided into 3 types. Type of air-to-air intercooler, air to water, and one shot.

1. Air to air

Air to air intercooler could be a type of the foremost wide utilized in cars these days. Of explicit interest during this kind of indentation intercoolers and changes in size ought to be as very little as attainable. Additionally, the connections and rubber hoses ought to be of fine quality to be ready to stand up to the pressure turbo.

2. Air to water

Intercooler air to water at first used for ships. On this kind of water to cool air circulating for, essentially works as the radiator water. The foremost necessary component during this sort off or this intercooler is that the pump. For that's sometimes connected with a pump mounted 12-volt batteries series or parallel.

3. Shot intercooler

Intercooler one shot has the high potential of air cooling and quite cool the turbo and therefore the air in no time. Intercooler like this is often not appropriate for everyday vehicles, except for vehicles Drag Race. Sometimes the material used for the intercooled one shot is N2.

1.2 Components: Principle components of Shell and Tube type heat exchanger

In air compressor, Shell and Tube heat exchanger is employed as intercooler. They're sometimes air-to-water intercooler. Principal parts of Shell and Tube heat exchanger are given as: Shell, shell cover, tubes, channel, channel cover, tube sheet, baffles and nozzles

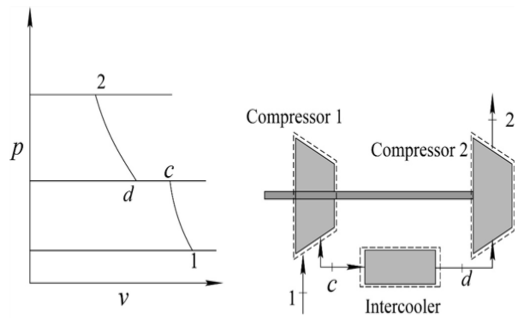


Fig 1.2.1 - Diagram of a typical shell and tube heat exchanger, showing the components.

Initial Design Consideration of Intercooler

There are varieties of practical tips which may result in the optimum design of a given heat exchanger. Basic is that the first duty is to perform its thermal duty with lowest price nonetheless give excellent performance in service reliability, the choice of fluid stream allocations ought to be of primary concern to the designer. There are several trade-offs in fluid allocation in heat transfer coefficients, available pressure drop, fouling tendencies and operative pressure.

1.3 Introduction to CFD:

Computational fluid dynamics, usually abbreviated as CFD, is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions. With high-speed supercomputers, better solutions can be achieved

Methodology:

In all of these approaches the same basic procedure is followed.

- During preprocessing
  - The geometry (physical bounds) of the problem is defined.
  - The volume occupied by the fluid is divided into discrete cells (the mesh). The mesh may be uniform or non-uniform.
  - The physical modeling is defined – for example, the equations of motion + enthalpy + radiation + species conservation
  - The simulation is started and the equations are solved iteratively as a steady-state or transient.
- Finally a postprocessor is used for the analysis and visualization of the resulting solution.

1.4 MODELS OF SHELL AND TUBE INTERCOOLER

Models for CFD Analysis

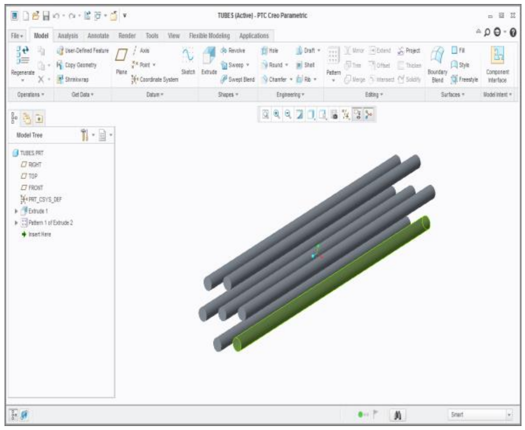


Fig 1.4.1 – Tubes inintercoolerWithout baffles

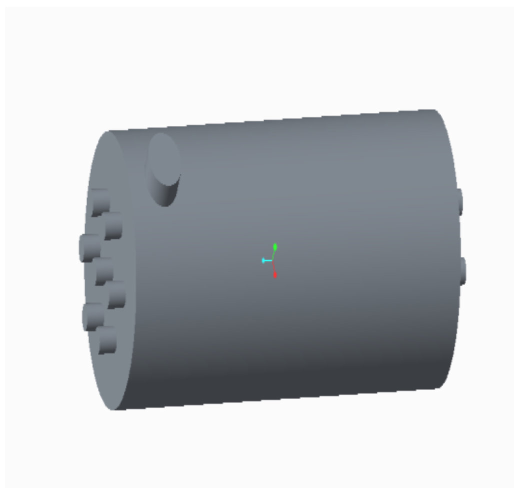


Fig 1.4.2 – 3D model of intercooler without baffles.

140^0 Baffles

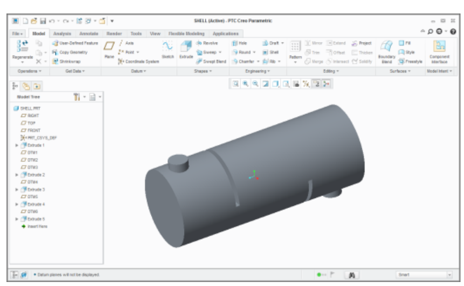


Fig 1.4.3– 3D model of shell with baffle cut

140^0 Baffles

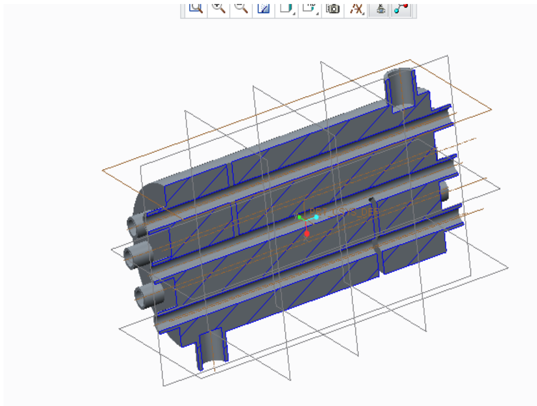


Fig 1.4.4– 3D model with 140^0 baffles

2.1 CFD – Analysis of Intercooler

The boundary conditions are considered from the journal paper "Analysis and Performance Enhancement of Intercooler In Two Stage Reciprocating Air Compressor Using CFD", by A.Sathyaraj, International Journal on Applications in Mechanical and Production Engineering, Volume 1: Issue 2: February 2015, pp 1-5, specified as [1] in References chapter.

Boundary Conditions:

Volumetric flow rate in shell = 0.0063m^3/s

Volumetric flow rate in tube = 0.00455m^3/s

Temperature and Pressure in tube are kept constant T1 = 307K, P1 = 1kg/cm^2

Boundary condition 1 = T 2= 379 K, P2= 2.29 kg/cm^2 = 224572.3Pa

Boundary condition 2 = T2= 385 K, P2= 2.25 kg/cm^2 = 220649.6Pa

Boundary condition 3 = T2= 390 K, P2= 2.25 kg/cm^2

Boundary condition 4 = T2= 400 K, P2= 2.29 kg/cm^2

Area of shell inlet = 3390mm^2 = 0.00339m^2

Velocity = Volumetric flow rate / Area = 0.0063/0

2.2 CFD Analysis of Intercooler Segmental Baffles- 140^0

Volumetric flow rate in tube = 0.00455m^3/s

Area of tube = 314.16mm^2 = 0.00031416m^2

Velocity = Volumetric flow rate / Area = 0.0045/0.002199 = 14.323m/s

Boundary condition 1 = T 2= 379 K, P2= 2.29 kg/cm^2 = 224572.3Pa

→→Ansys → workbench→ select analysis system → fluid flow fluent → double click

→→Select geometry → right click → import geometry → select browse →open part → ok

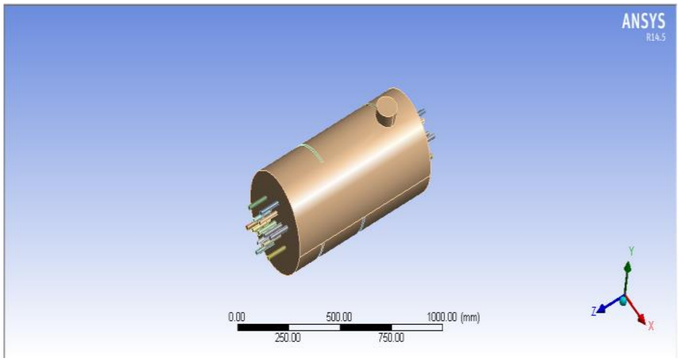


Fig2.2.1 - Imported model of intercooler with baffles

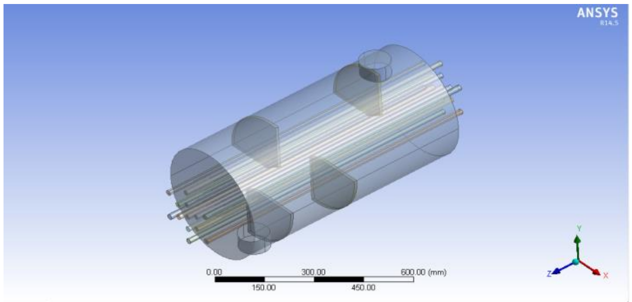


Fig 2.2 – Model of intercooler with baffles in transparent

→→ Select mesh on work bench → right click →edit → select mesh on left side part tree → right click → generate mesh →

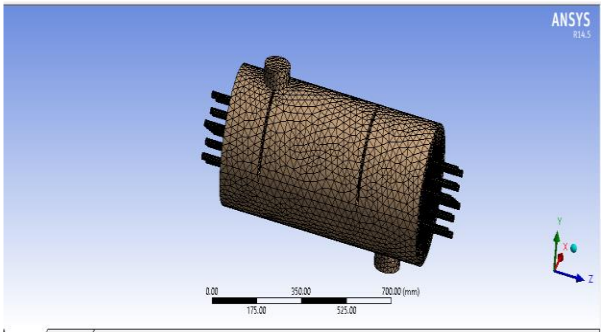


Fig 2.2.2- Meshed model of intercooler with baffles

Select faces → right click → create named section → enter name → hot air inlet & outlet

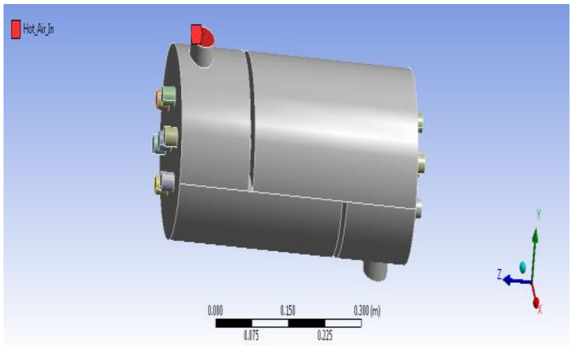


Fig 2.2.3– Hot Air Inlet of intercooler with baffles

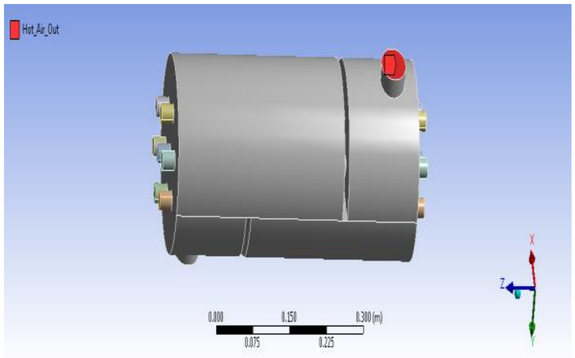


Fig 2.2.4 – Hot Air Outlet of intercooler with baffles

Select faces → right click → create named section → enter name → cold air inlet & outlet

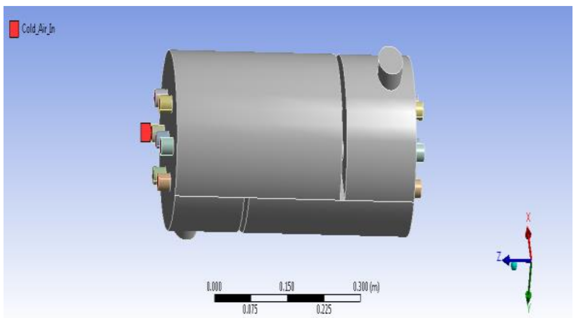


Fig 2.2.5 – Cold Air Inlet of intercooler with baffles.

3.1RESULTS

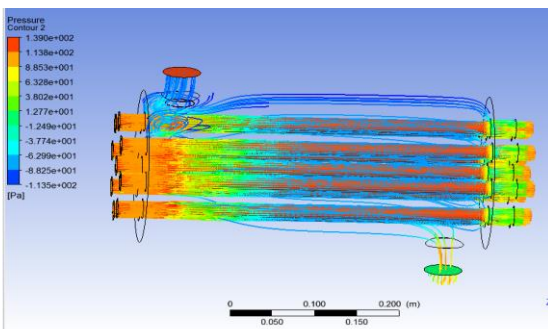


Fig 3.1.1 Contours of Pressure at boundary condition 1 of intercooler without baffles

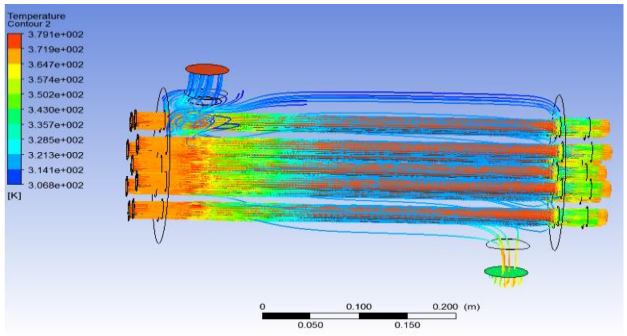


Fig 3.1.2 – Contours of Temperature at boundary condition 1 of intercooler without baffles

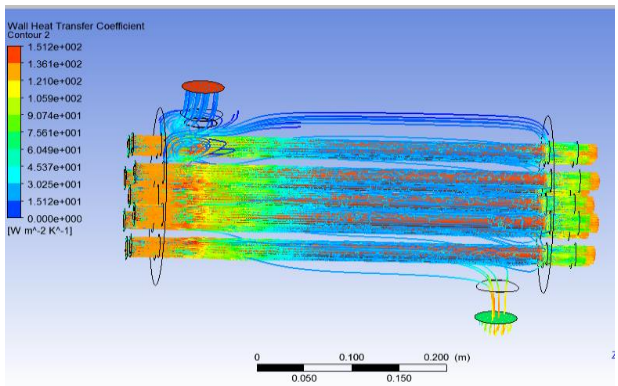


Fig 3.1.3 – Contours of wall heat transfer coefficient at boundary condition 1 of intercooler without baffles

Boundary condition 2 = T 2= 385 K, P2= 2.25 kg/cm^2 = 220649.6Pa

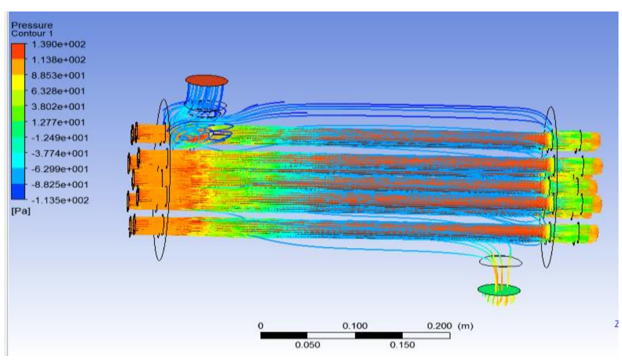


Fig 3.1.4 – Contours of Pressure at boundary condition 2 of intercooler without baffles

3.2 CFD – ANALYSIS RESULTS

Without Baffles

	PRESSURE (Pa)	TEMPERATURE (K)	WALL HEAT TRANSFER COEFFCIENT (W/m^{2}K)
Boundary Condition 1	139.2	379.1	151.2
Boundary Condition 2	139	385.1	151.2
Boundary Condition 3	139	390.1	151.2
Boundary Condition 4	139	400.2	151.2

Table – CFD analysis results of Intercooler in Multistage Compressor Systemwithout Baffles

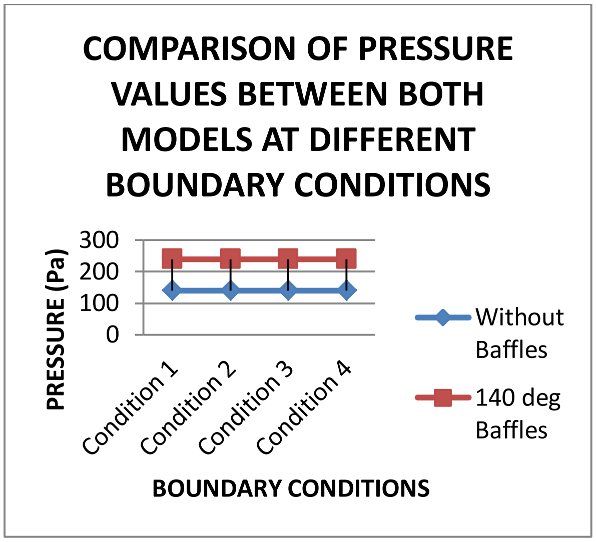
The above table presents the results of pressure, temperature and wall heat transfer coefficient of intercooler without baffles by performing CFD analysis.

140^0 Baffles

	PRESSURE (Pa)	TEMPERATURE (K)	WALL HEAT TRANSFER COEFFCIENT (W/m^{2}K)
Boundary Condition 1	238.6	379	529.6
Boundary Condition 2	238.6	385	529.6
Boundary Condition 3	238.6	390	529.6
Boundary Condition 4	238.6	400	529.6

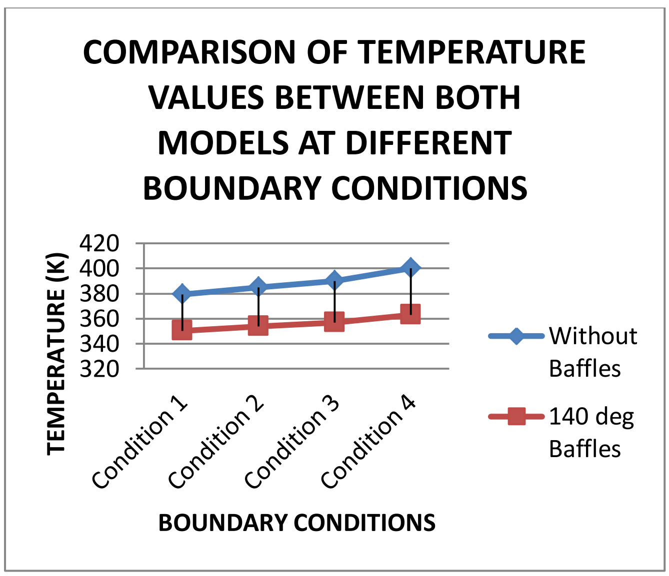
Table – CFD analysis results of Intercooler in Multistage Compressor System140^0 Baffles.

The above table presents the results of pressure, temperature and wall heat transfer coefficient of intercooler with 140^0 baffles by performing CFD analysis.



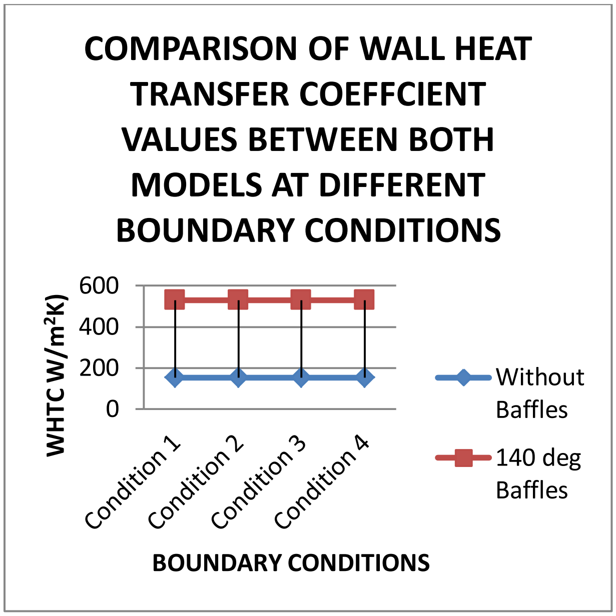
Graph – Comparison of Pressure Values Between Both Models at Different Boundary Conditions.

From the above graph it is observed that the pressure and wall heat transfer coefficients are constant by changing the boundary conditions.



Graph – Comparison of Temperature Values Between Both Models at Different Boundary Conditions

From the above graph it is observed that the temperature is decreased more at boundary condition 1. The temperature is reduced when baffles are used.



Graph – Comparison of wall heat transfer coefficient values for two models and different materials

From the above graph it is observed that the temperature is reduced when baffles are used and also wall heat transfer coefficient is more.

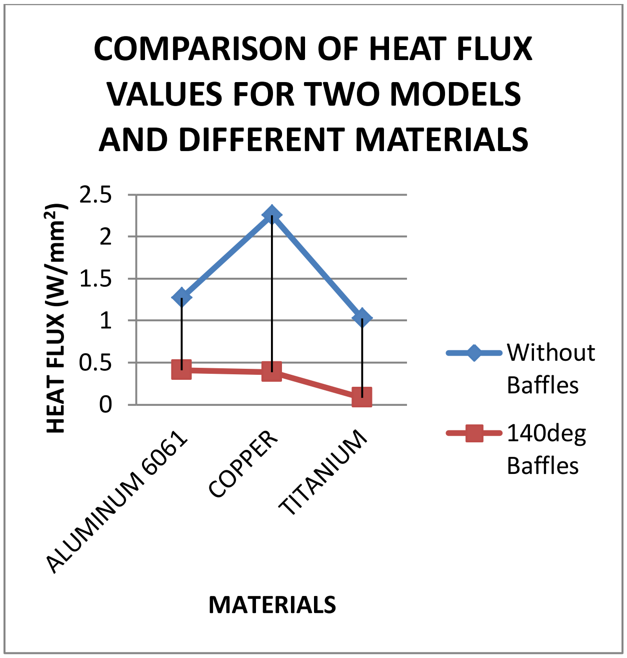
THERMAL ANALYSIS - RESULTS

Heat Flux between 140^0 Baffles and Without Baffles

	HEAT FLUX (W/mm^2)		
	Aluminum	**Copper**	**Titanium**
140^0 Baffles	0.40805	0.3874	0.077422
Without Baffles	1.2713	2.2548	1.0302

Table – Thermal analysis results of Intercooler in Multistage Compressor System between 140^0 Baffles and Without Baffles

The above table presents the results of heat flux of intercooler with and without baffles by performing thermal analysis using different materials.



`From the above graph it is observed that the heat flux is more for without baffles model than with baffles model. This is due to the fact that the heat-transfer rate increases with an increase of the beat-transfer area and the overall heat-transfer coefficient.

CONCLUSION

In this thesis, analytical investigations are done on the shell and tube intercooler without and with 140^0 baffles and optimized for better heat transfer rate. The analysis is performed using forced convective heat transfer to determine flow characteristics of air flowing under turbulent flow conditions.

CFD analysis is done under different boundary conditions. The temperature and pressure of hot air are changed and the analysis is carried out. By observing the analysis results, the pressure and wall heat transfer coefficients are constant by changing the boundary conditions. The temperature is decreased more at boundary condition 1. The temperature is reduced when baffles are used and also wall heat transfer coefficient is more. The increase heat-transfer coefficient affects the cost, as it depends on both the velocities of gas and water. By forcing the fluids through the intercooler at higher velocity, the heat-transfer coefficient is increased, but this higher velocity results in a large pressure drop through the intercooler and require larger pumping power of fluid.

By observing the results, the heat flux is more for without baffles model than with baffles model. This is due to the fact that the heat-transfer rate increases with an increase of the heat-transfer area and the overall heat-transfer coefficient. But the increase of area results in a larger size and a higher cost of the intercooler.

Copper has more heat flux value than other two materials. But the main disadvantage of Copper is its more weight when compared with that of Aluminum and Titanium.

REFERENCES

1. A.Sathyaraj, Analysis and Performance Enhancement of Intercooler In Two Stage Reciprocating Air Compressor Using CFD, International Journal on Applications in Mechanical and Production Engineering Volume 1: Issue 2: February 2015, pp 1-5.

1. Y. Wu J. F. Hamilton, W. Shenghong, "Optimization of Shell-and-Tube Intercooler in Multistage Compressor System" (1982), International Compressor Engineering Conference. Paper 399.
2. ShahramAzizifar and Salem Banooni, Modeling and optimization of industrial multistage compressed air system using actual variable effectiveness in hot regions, Advances in Mechanical Engineering, 2016, Vol. 8(5) 1–10
3. Pawan Kumar Gupta, S.P.Asthana, Neha Gupta, A study based on design of air compressor intercooler, INTERNATIONAL JOURNAL OF RESEARCH IN AERONAUTICAL AND MECHANICAL ENGINEERING, Vol.1 Issue.7, November 2013, Pgs: 186-203
4. D. Gillespie – Oxford University, R. Stieger – Rolls-Royce plc, M. Christodoulou – Scitek Consultants, Cross-corrugated Intercooler and Installation
5. MohdMuqeem, Turbocharging With Air Conditioner Assisted Intercooler, IOSR Journal of Mechanical and Civil Engineering (IOSRJMCE), ISSN : 2278-1684 Volume 2, Issue 3 (Sep-Oct 2012), PP 38-44
6. G. Starace, E. Carluccio, D. Laforgia, Automotive compact surpercharge-air intercooler numerical analysis, International Heat Transfer Conference, DOI: 10.1615/IHTC13.p22.330, 10 pages