INTERNATIONAL JOURNAL OF MERGING TECHNOLOGY AND ADVANCED RESEARCH IN COMPUTING

IJMTARC – VOLUME – IX – ISSUE – 38, JUL - SEP, 2022

ISSN: 2320-1363

DESIGN AND ANALYSIS OF HEAT PUMP USING CAE TOOLS

S Umar, Shaik Munawar Basha, Shaik Mohammed Wasim Akram, Shaik Suhail Basha, Shaik Mohammad Suhail, Mr G.Phani Kumar Reddy

Dept. of Mechanical Engineering, Brindavan Institute of Technology and Science, Kurnool, Andhra Pradesh, India

ABSTRACT:

The Coolant pump assembly is a system to move heat around the engine. The main purpose of the assembly is to carry away the intense heat generated by the combustion in the engines and other applications include heating parts of the engine for cold weather. The engine runs best at a fairly high temperature. When the engine is cold, components wear out faster, and the engine is less efficient and emits more pollution. So another important job of the cooling system is to allow the engine to heat up as quickly as possible, and then to keep the engine at a constant temperature. The heat pump assembly is modeled using Catia and the analysis is carried out in Ansys. The heat pump system is subjected to different fluctuating temperatures from 260^{o}C to room temperature. So, detailed thermal and structural analysis was carried out for designing the system and studied different modifications for proposing the optimum design with reduced deformations and stresses due to thermal loads.

I.INTRODUCTION

A heat pump is a device that transfers heat energy from a source of heat to a destination called a "heat sink". Heat pumps are designed to move thermal energy in the opposite direction of spontaneous heat transfer by absorbing heat from a cold space and releasing it to a warmer one. A heat pump uses a small amount of external power to accomplish the work of transferring energy from the heat source to the heat sink.

While air conditioners and freezers are familiar examples of heat pumps, the term "heat pump" is more general and applies to many heating, ventilating, and air conditioning devices used for space heating or space cooling. When a heat pump is used for heating, it employs the same basic refrigeration-type cycle used by an air conditioner or a refrigerator, but in the opposite direction - releasing heat into the conditioned space rather than the surrounding environment. In this use, heat pumps generally draw heat from the cooler external air or from the ground.

In heating mode, heat pumps are three to four times more effective at heating than simple electrical resistance heaters using the same amount of electricity. The typical installation cost of a heat pump is about 20 times greater than that of resistance

Overview

Heat energy naturally transfers from warmer places to colder spaces. However, a heat pump can reverse this process, by absorbing heat from a cold space and releasing it to a warmer one. Heat is not conserved in this process and requires some amount of external energy, such as electricity. In heating, ventilation and air conditioning (HVAC) systems, the term heat pump usually refers to vapor-compression refrigeration devices optimized for high efficiency in both directions of thermal energy transfer. These heat pumps can be reversible, and work in either direction to provide heating or cooling to the internal space.

Heat pumps are used to transfer heat because less high-grade energy is required than is released as heat. Most of the energy for heating comes from the external environment, only a fraction of which comes from electricity (or some other high-grade energy source required running a compressor). In electrically-powered heat pumps, the heat transferred can be three or four times larger than the electrical power consumed, giving the system a coefficient of performance (COP) of 3 or 4, as opposed to a COP of 1 for a conventional electrical resistance heater, in which all heat is produced from input electrical energy.

Heat pumps use a refrigerant as an intermediate fluid to absorb heat where it vaporizes, in the evaporator, and then to release heat where the refrigerant condenses, in the condenser. The refrigerant flows through insulated pipes between the evaporator and the condenser, allowing for efficient thermal energy transfer at relatively long distances.

II - LITERATURE SURVEY

This chapter provides an overview of the literature on the works carried out in the analysis of Heat Pumps and emergence of ANN simulation for thermal systems which are relevant for present studies.

2.1 Analysis of Heat Pumps

Several different approaches have been devised to the study Heat Pumps. Early attempts include analytical solutions of the Nusselt number for a large collection of duct shapes under laminar flow (Shah and London, 1978), with either constant wall temperature or constant wall heat flux boundary conditions, using different techniques such as conformal mapping (Sastry 1964, 1965) or Galerkin integral methods (Haji-heikh et al 1983). Many simplified models for Heat Pumps have also been proposed. An analytical approach for predicting the air-side performance of a single-phase heat exchanger with louvered fins was developed (Sahnoun and Webb 1992). Their model predicted heat transfer coefficients with errors of as much as 25%. For calculating the air-side heat transfer in Heat Pumps under condensing conditions an analytical method has been described (Ramadhyani 1998). Recently, Srinivasan and Shah (1997) examined condensation phenomena occurring in compact Heat Pumps. Other attempts to analyze transport phenomena in the air-side, within the fin-tube passages (Kushida et al 1986; Bastani et al 1992; Torikoshi et al 1994), and in the water-side, 10 inside the tube bends (Goering et al 1997), have been carried out with CFD techniques assuming isothermal fins.

Ranganayakulu and Seetharamu (1999) performed a steady state simulation of a single-phase heat exchanger using finite elements. Their analysis included the effect of one-dimensional heat conduction at the wall, no uniformity in the inlet fluid flow, and a few different models of temperature distributions Due to the fact that no analytical or accurate numerical solutions are available; the information has been usually derived experimentally.

A large amount of experimental information about transport phenomena in single-phase, cooling, and evaporator Heat Pumps are reported in the open literature (Webb 1980; Kakac et al 1981; Kays and London 1984; Shah et al 1990). For instance, Beecher and Fagan (1987) determined performance data for single-phase finned-tube Heat Pumps; Jacobi and Goldschmidt (1990) characterized, experimentally, heat and mass transfer performance of a condensing heat exchanger. Similar studies were also examined by McQuiston (1976 and 1978), Mirth and Ramadhyani (1995), and Yan and Sheen (2000). Thermal performance data for evaporators have been developed by Panchal and Rabas (1993). These findings are all based on the experimentally determined overall, air-side and water-side heat transfer coefficients. A few studies have been carried out to find correlations for the performance of compact Heat Pumps. The most representative examples are those for single phase operating conditions (Gray and Webb 1986), for Heat Pumps operating under wet conditions (McQuiston 1978), and for evaporators (Kandlikar 1991). The review results revealed that the achievement of the thermal comfort conditions optimizes the size of the Heat Pumps.

These review results revealed that the provision of baffles in the Heat Pumps causes huge pressure drop of the heat transfer fluid. This limitations can be overcome by using dimples, fins, full length twisted tapes and vortex generators. Also review results revealed that the proper designs for the fluid flow in compact Heat Pumps is essential. The axial heat conduction affecting parameters are Reynolds number (Re), thickness of separating wall (ts) and thermal conductivity ratio (Kr).

2.2 Parallel Heat Pump

An extensive research work has been done till date on the Heat Pumps by changing different parameters to meet the industry requirements. Lunsford (1998) provided some methods for increasing shelland-tube exchanger performance. The methods considered whether the exchanger is performing correctly to begin with, excess pressure drop capacity in existing exchangers, the re-evaluation of fouling factors and their effect on exchanger calculations, and the use of augmented surfaces and enhanced heat transfer. Sparrow and Reifschneider (1986) conducted experiments on the effect of inter baffle spacing on heat transfer. Huadong Li and Volker Kott Ke (1998) conducted experiments on the Effect of leakage on pressure drop and local heat transfer in Parallel Heat Pumps for staggered has slight contribution to the local heat transfer at the surfaces of the external tubes of the tube bundle, but reduces greatly the per-compartment average heat transfer. Morcos and Shafey (1995) carried out an experimental analysis to study the performance analysis of a plastic heat exchanger.

Qiao He and Wennan Zhang (2001) presented a theoretical analysis and an experimental test on a Parallel latent heat storage exchanger. The prediction by the mathematical model on the performance of the heat storage exchanger is reasonable and in agreement with experimental measurements. Rozzi et al (2007) worked on convective heat transfer and friction losses in helically enhanced tubes for both Newtonian and non Newtonian fluids. Four fluid foods, namely, whole milk, cloudy orange juice, apricot and apple puree, are tested in a heat exchanger. Both fluid heating and cooling conditions are considered. The experimental outcome confirms that helically corrugated tubes are particularly effective in enhancing convective heat transfer for generalized Reynolds number ranging from about 800 to the limit of the transitional flow regime.

III - OBJECTIVES AND METHODOLOGY

The objective of this project work is to successfully develop a design of a heat exchanger for minimizing of its entropy. The mechanism is to be reliable, simple, cost-effective and practically feasible. The aim of this heat exchanger is to provide constrained thermodynamic optimization, so as to enable the required measurement of Entropy in the heat exchanger. This system is also supposed to enhance the comfort temperature and the favorable conditions.

The methodology adopted to use standard and presently used components in design rather than to design all components from ground up. The advantage of this method is that, you do not have to spend ridiculous amount and entropy level in testing the integrity of each part as they have already proved their worth in real world applications.

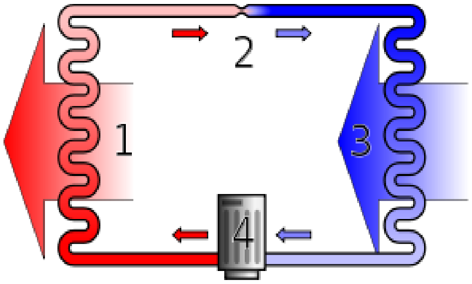
Initially the design was adopted from an already existing heat exchanger and minor changes were made to suite our purpose, first devised was based on using the fluid between the wall, shell and the pipes set and lowering each level of entropy of the system. This mechanism was later taken in testing phase due to following conditions.

1. Heat transfer coefficient on the heat pump has been obtained from tubes.
2. Pressure drop have been obtained for heat pump.
3. Heat Pump process has to be obtained.
4. Carry out design and optimization of heat pump.

Due to these conditions, the design was changed and a fully new design was defined. The model also uses the same mechanism setup. The software to be used in design is Catia V5 and testing of design is Ansys.

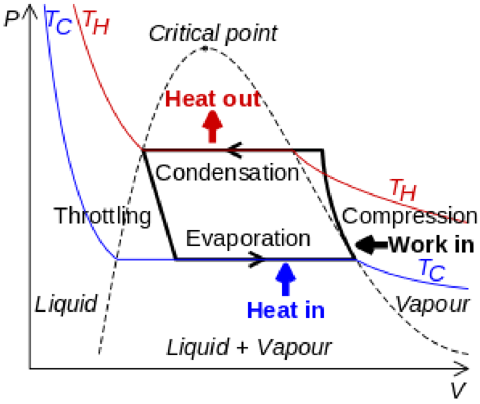
IV - WORKING METHODOLOGY OF HEAT PUMP

The working fluid, in its gaseous state, is pressurized and circulated through the system by a compressor. On the discharge side of the compressor, the now hot and highly pressurized vapor is cooled in a heat exchanger, called a condenser, until it condenses into a high pressure, moderate temperature liquid. The condensed refrigerant then passes through a pressure-lowering device also called a metering device. This may be an expansion valve, capillary tube, or possibly a work-extracting device such as a turbine. The low-pressure liquid refrigerant then enters another heat exchanger, the evaporator, in which the fluid absorbs heat and boils. The refrigerant then returns to the compressor and the cycle is repeated.



It is essential that the refrigerant reaches a sufficiently high temperature, when compressed, to release heat through the "hot" heat exchanger (the condenser). Similarly, the fluid must reach a sufficiently low temperature when allowed to expand, or else heat cannot flow from the ambient cold region into the fluid in the cold heat exchanger (the evaporator).

In particular, the pressure difference must be great enough for the fluid to condense at the hot side and still evaporate in the lower pressure region at the cold side. The greater the temperature difference, the greater the required pressure difference, and consequently the more energy needed to compress the fluid.



Thus, as with all heat pumps, the coefficient of performance (amount of thermal energy moved per unit of input work required) decreases with increasing temperature difference.

V - DESIGN METHODLOGY OF HEAT PUMP

5.1 Introduction to CATIA

CATIA (Computer Aided Three-dimensional Interactive Application) is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Dassault Systems. Written in the C++ programming language, CATIA is the cornerstone of the Dassault Systems product lifecycle management software suite.

CATIA competes in the high-end CAD/CAM/CAE market with Cero Elements/Pro and NX (Unigraphics).

CATIA can be applied to a wide variety of industries, from aerospace and defense, automotive, and industrial equipment, to high tech, shipbuilding, consumer goods, plant design, consumer packaged goods, life sciences, architecture and construction, process power and petroleum, and services. CATIA V4, CATIA V5, Pro/ENGINEER, NX (formerly Unigraphics), and Solid Works are the dominant systems.

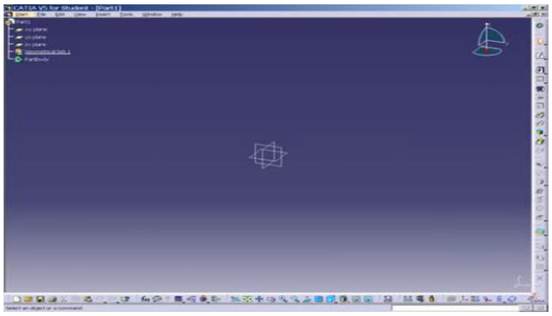


Fig: 5.1: Home Page of CatiaV5

Modeling of Heat Pump in CATIA V5

This Heat Pump is designed using CATIA V5 software. This software used in automobile, aerospace, consumer goods, heavy engineering etc. it is very powerful software for designing complicated 3d models, applications of CATIA Version 5 like part design, assembly design.

The same CATIA V5 R20 3d model and 2d drawing model is shown below for reference. Dimensions are taken from. The design of 3d model is done in CATIA V5 software, and then to do test we are using below mentioned software's.

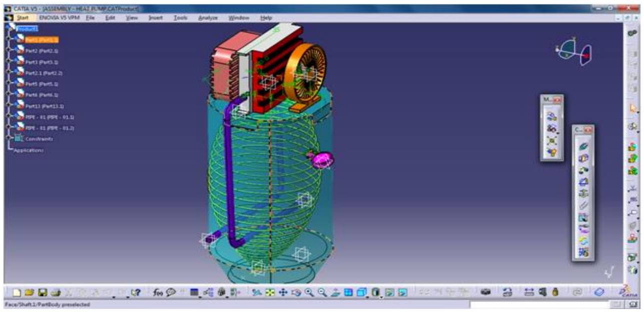


Fig: 5.2: Model design in CATIA-V5

VI - ANALYSIS OF HEAT PUMP

6.1 Procedure for FE Analysis Using ANSYS:

The analysis of the parallel heat exchanger is done using ANSYS. For compete assembly is not required, is to carried out by applying moments at the circulation of the fluid location along which axis we need to mention. Fixing location is bottom legs.

6.2 Preprocessor

In this stage the following steps were executed:

- **Import file in ANSYS window**

  File Menu > Import> STEP > Click ok for the popped up dialog box > Click

  Browse" and choose the file saved from CATIAV5R20 > Click ok to import the file

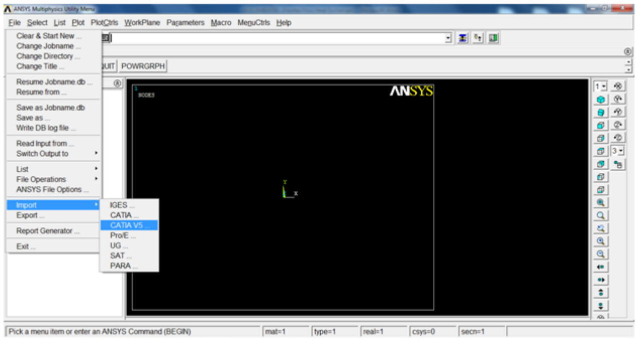


Fig.6.1: Import panel in Ansys.

6.2.1 Meshing:

Mesh generation is the practice of generating a polygonal or polyhedral mesh that approximates a geometric domain. The term "grid generation" is often used interchangeably. Typical uses are for rendering to a computer screen as finite element analysis or computational fluid dynamics. The input model form can vary greatly but common sources are CAD, NURBS, B-rep and STL (file format). The field is highly interdisciplinary, with contributions found in mathematics, computer science, and engineering. Three-dimensional meshes created for finite element analysis need to consist of tetrahedral, pyramids, prisms or hexahedra. Those used for the finite volume method can consist of arbitrary polyhedral. Those used for finite difference methods usually need to consist of piecewise structured arrays of hexahedra known as multi-block structured meshes.

Meshing is an integral part of the computer-aided engineering (CAE) simulation process. The mesh influences the accuracy, convergence and speed of the solution. Furthermore, the time it takes to create a mesh model is often a significant portion of the time it takes to get results from a CAE solution. Therefore, the better and more automated the meshing tools, the better the solution. From easy, automatic meshing to a highly crafted mesh, ANSYS provides the ultimate solution. Powerful automation capabilities ease the initial meshing of a new geometry by keying off physics preferences and using smart defaults so that a mesh can be obtained upon first try. Additionally, users are able to update immediately to a parameter change, making the handoff from CAD to CAE seamless and aiding in up-front design. Once the best design is found, meshing technologies from, ANSYS provide the flexibility to produce meshes that range in complexity from pure hex meshes to highly detailed

Hybrid meshes.

VII - DISCUSSION ON ANALYSYS RESULT

7.1 Results of Nodal Temperature:

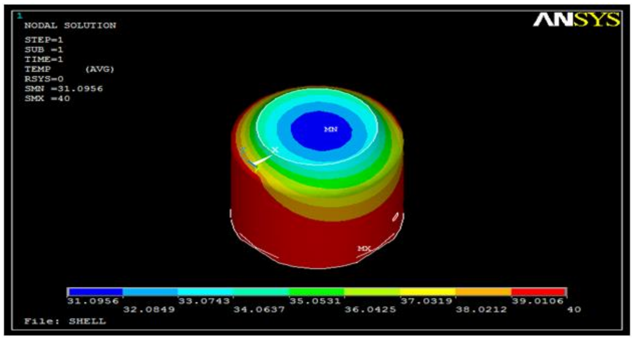


Fig: 7.1: Nodal Temperature of Shell

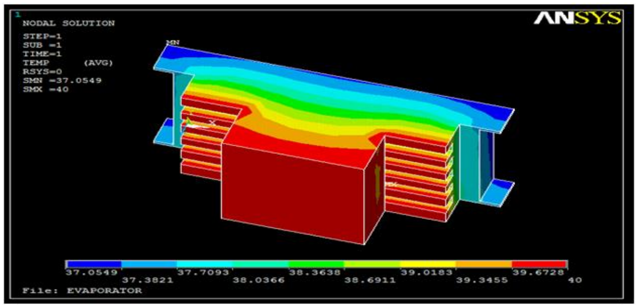


Fig: 7.2: Nodal Temperature of Evaporator

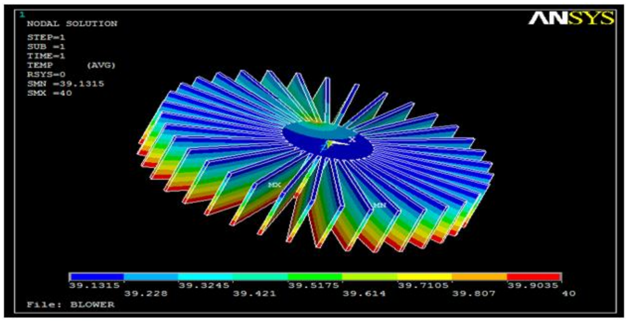


Fig: 7.3: Nodal Temperature of Blower

7.2 Results of Thermal Gradient:

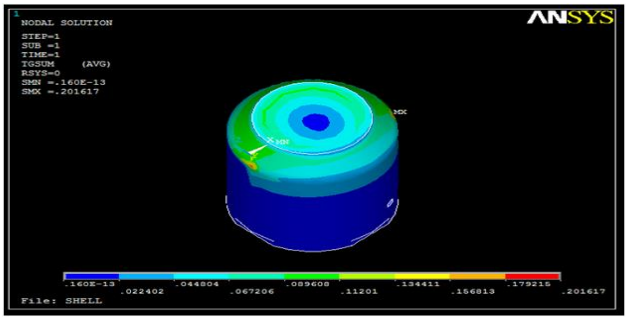


Fig: 7.18: Thermal Gradient Analysis of Shell

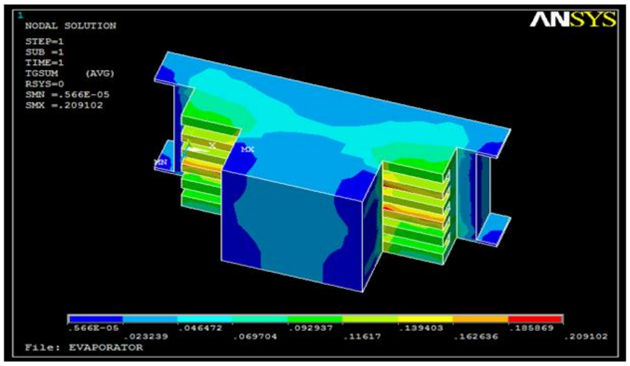


Fig: 7.19: Thermal Gradient Analysis of Evaporator

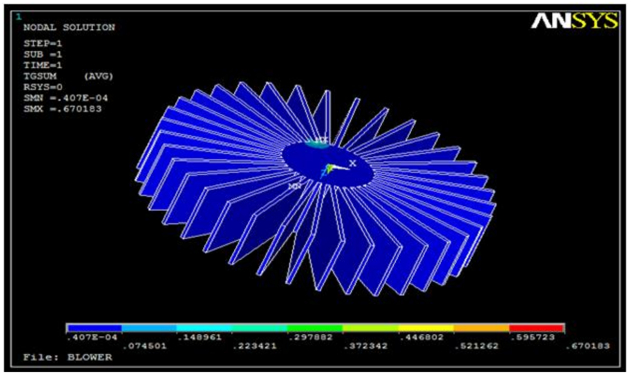


Fig: 7.20: Thermal Gradient Analysis of Blower

6.3 Results of Thermal Flux:

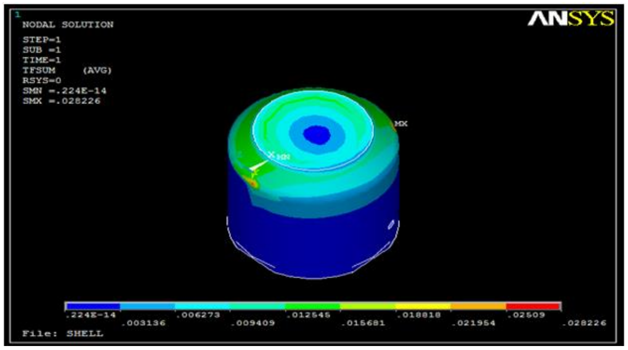


Fig: 7.35: Thermal Flux Analysis of Shell

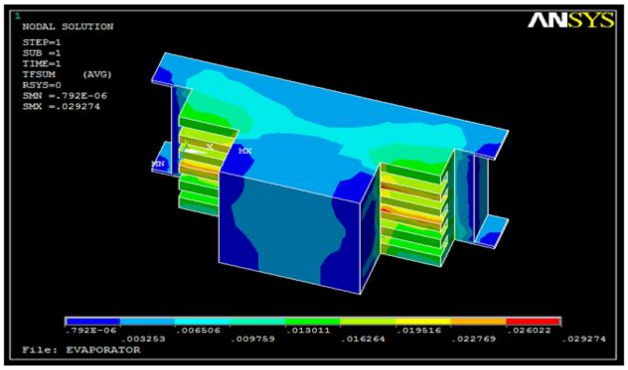


Fig: 7.36: Thermal Flux Analysis of Evaporator

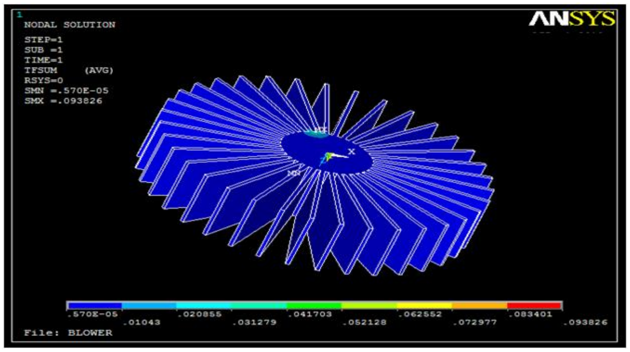


Fig: 7.37: Thermal Flux Analysis of Blower

Results of Heat Flow:

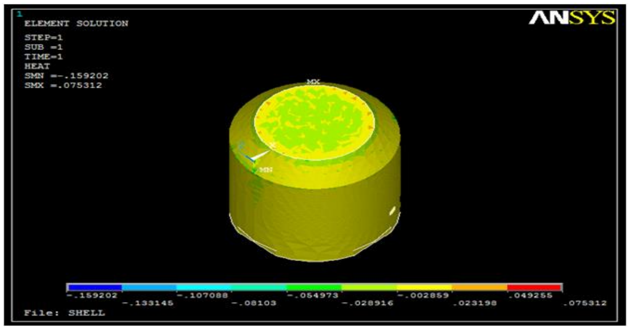


Fig: 7.35: Heat Flow Analysis of Shell

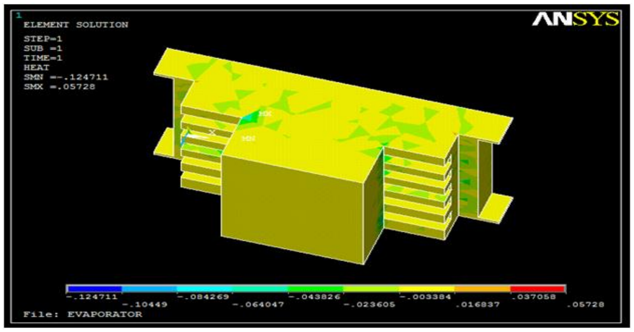


Fig: 7.36: Heat Flow Analysis of Evaporator

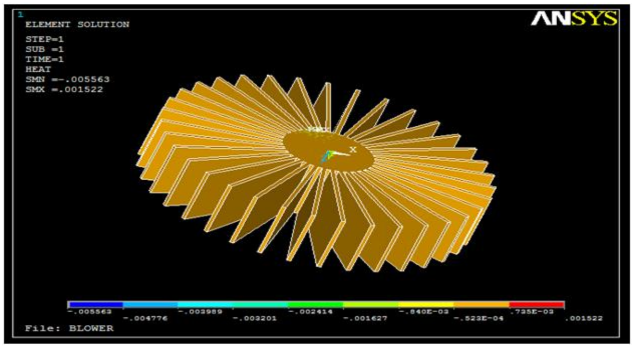


Fig: 7.37: Heat Flow Analysis of Blower

VIII - CONCLUSION

It can be seen from the above result that, our objective to minimization the entropy in heat exchanger using constrained thermodynamic optimization which has been successful. As shown above figures the Nodal Temperature of the complete design is meshed and solved using Ansys and Nodal Temperature for Evaporator is 37.05, for Shell is 31.09 and for Blower is 39.13. This is showing us that clearly each component in assembly is having minor entropy. The maximum Thermal gradient is coming, this solution solving with the help of Ansys software so that the maximum Thermal gradient for Evaporator is 0.209, for Shell is 0.201 and for Blower is 0.670.

The maximum Thermal flux is coming, this solution solving with the help of Ansys software so that the maximum Thermal flux for Evaporator is 0.029, for Shell is 0.028 and for Blower is 0.093. That the maximum Heat flow for Evaporator is 0.057, for Shell is 0.075 and for Blower is 0.0015. So we can conclude our design parameters are approximately correct. The design of the heat pump mechanism worked flawlessly in analysis as well, all these facts point to the completion of our objective in high esteem.

IX. REFERENCES

- Indian Standard (IS: 4503-1967): Specification for Heat pump, BIS 2007, New Delhi.
- Rajeev Mukharji, “Effective design of heat pump”, American Institute of Chemical Engineering, 1988.
- Hari Haran, Ravindra Reddy and Sreehari, “Thermal Analysis of heat pump Using C and Ansys” , International Journal of Computer Trends and Technology (IJCTT) – volume 4 Issue 7–July 2013
- Yusuf Ali Kara, OzbilenGuraras, ―A computer program for designing of heat pump ‖, Applied Thermal Engineering 24(2004) 1797-1805
- V.K. Patel, R.V. Rao, “Design optimization of heat pump using particle swarm optimization technique”, Applied Thermal Engineering 30 (2010) 1417-1425
- Versteeg, H.K., Malalasekera, W., An introduction to computational fluid dynamics: the finite volume method.
- M. M. El-Fawal, A. A. Fahmy and B. M. Taher, “Modelling of Economical Design of heat pump Using Specified Pressure Drop”, Journal of American Science
- JiangfengGuo, Lin Cheng, MingtianXu, “Optimization design of heat pump by entropy generation minimization and genetic algorithm”, Applied Thermal Engineering 29 (2009) 2954–2960.
- Pignotti, “Relation between the Thermal Effectiveness of Overall heat pump Geometries”, J. Heat Transfer 111(2), 294-299 (May 01, 1989), asme.org.
- SepehrSanaye, Hassan Hajabdollahi, “Multi-objective optimization of heat pump”, Applied Thermal Engineering 30 (2010) 1937-1945.
- Taborek, J., Evolution of heat pump design techniques, Heat Transfer Eng. **1**, No. 1, 15-29 (1979)
- M. Thirumarimuegan, ―Performance analysis of heat pump using Miscible system‖, American journal of applied science, 2008, 5(5): 548-552.al, V
- M. Yilmaz, O.N. Sara, S. Karsli, Performance evaluation criteria for heat pump based on second law analysis, Exergy, An International Journal 1 (4) (2001) 278–294.
- Bejan, Entropy Generation through Heat and Fluid Flow, Wiley, New York, 1982.
- Bejan, A study of entropy generation in fundamental convective heat transfer, ASME Journal of Heat Transfer 101 (1979) 718–725.
- J.V.C. Vargas, A. Bejan, D.L. Siems, Integrative thermodynamic optimization of the crossflow heat exchanger for an aircraft environmental control system, Transactions of the ASME 123 (August) (2001) 760–769.
- U. Ogˇulatu, F. Doba, T. Yilmaz, Irreversibility analysis of cross flow Heat Pumps, Energy Conversion and Management 41 (2000) 1585–1599.