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OPTIMIZED DESIGN AND ANALYSIS OF AIR HANDLING UNIT LEVERAGING CAE TOOLS

B. ADI NARAYANA[*1], CH. VENKATESWARA RAJU[*2], CH. SURESH[*3]
[*1, 2, 3]Assistant Professor, Dept. of Mechanical Engineering.
A.M Reddy Memorial College of Engineering and Technology, Andhra Pradesh.

Abstract: Air Handling Unit is defined as a self-contained unit that the conditions of air vary while passing through it and reach to the desired temperature and humidity. To perform variations in weather conditions various processes such as heating, cooling, humidification, dehumidification and mixing are applied. In this research thermodynamic modeling and analysis of air handling units approaching minimum energy consumption is achieved. The objective function for analyzing is pressure drop of air crossing coil per cooling and heating load of the system. This function comprises all thermal and geometrical parameters of the coils such as coil surface area, number of rows, fin spacing and air side pressure drop of the coil. The optimization results are to compose of minimum pressure drop, optimum area, and optimum number of rows and fin spacing. The effects of varying the cooling and heating load, fin efficiency and the surface area of the coil on fan power consumption are investigated as well. A simulation results to experimental results, gained with a test bed. This method is used to design the unit in modeling tool Catia, which is simple method as compared with the other design methods. These work gives the combination of theoretical and software tool to provide a comparative analysis in the Ansys for the duct size.

I- INTRODUCTION

In the present day, as the population increases the need for comfortness also increases. The human being needs more comfortness because of inferior environment (like light, sound, machine which produce heat). Sound, light and heat affect human comfort a lot. They may adversely affect the human comfort positively or negatively. Researchers suggest that, human body is used to be comfortable at a temperature of 22ºC to 25ºC. When the temperature of room is lower or higher than this temperature, than the human body feels uncomfortable. This is because, the human body is structured in a way that, it should receive a certain amount of light, failure to which it can cause sunburns and other skin conditions.

There are many types of air conditioning system like window air conditioners, split air conditioners etc. but these AC's system are used in small room or office where cooling load required is low. When the cooling load required is very high like multiplex building, hospital etc. central AC's system are used. In central AC's system the cooled air is directly not distributed to the rooms. The cooled air from the air conditioning equipment must be properly distributed to rooms or spaces to be cold in order to provide comfort condition. When the cooled air cannot be supplied directly from the air conditioning equipment to the spaces to be cooled, then the ducts are installed. The duct systems convey the cold air from the air conditioning equipment to the proper air distribution point and also carry the return air from the room back to the air conditioning equipment for reconditioning and recirculation.

Air Handling Unit (AHU)

Air handling unit (AHU), is a device used to circulate the air as part of a heating, ventilating, and air-conditioning (HVAC) system. An air handling unit is usually a big metal box having a blower, chambers, heating or cooling elements, dampers and sound attenuators. AHU generally connect to a ductwork ventilation system that allocates the cooled air through the house or rooms and takings it to the AHU.

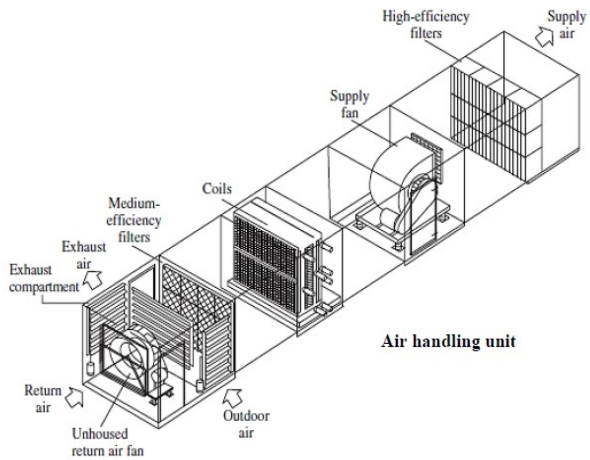

Fig: Air Handling Unit

The basic function of the AHU is take in outside air, condition it and supply fresh air to a building. All exhaust air is discharged, which secures an acceptable indoor air quality. Depending on the required temperature of the conditioned air, the fresh air is either heated by a recovery unit or heating coil, or cooled by a cooling coil.
In buildings, where the hygienic requirements for air quality are lower, some of the air from the rooms can be re-circulated by a mixing chamber, and result in significant energy savings. A mixing chamber has dampers for controlling the ratio between the return, outside, and exhaust air.

II - LITERATURE SURVEY

Thermal Comfort and Indoor Air Quality

The part played by humidity in the perception of thermal comfort cannot be exaggerated, as minor shifts in RH will have a sharp impact on microbial growth, in particular, at lower RH levels i.e. less than 30%. Typical causes for moisture problems like building tightness, penetration and thermal bridge were listed with suggestive references being made for limiting fungal growth. The ill-effects of reduced and excessive humidity levels were mentioned. Studies of the quantitative discomfort at different RH settings and associated thermal comfort across an exposure range of 20ºC, 60 % RH to 26ºC, 90 % RH were elaborated pointing out a favorable mix of parameters.

Rohles (1974) found a strong relationship between air velocity, air temperature, skin temperature and thermal sensation. Based on this, it was recommended that an extended summer comfort zone in which air movement up to 0.8 m/s compensated for elevated temperature (Tine et al 2002, Cheong et al (1999). This extended zone was incorporated into the ASHRAE Standard 55-1981.

Marc and Edward (1993) observed a draft risk data for a turbulence intensity of 40% (typical of indoor office environments) as applied in the standard temperature of 20ºC to 26ºC. Using the draft risk curve, air movement is restricted to 0.12 m/s at 20ºC and 0.4 m/s at 26ºC, which is extended to 0.8 m/s at 29ºC (Rydberg and Norback 1949). Thus it can produce a zone of occupant controlled comfort conditions.

The humidity problems in buildings can arise from several reasons including poor design of the building itself, malfunction of the HVAC system, leakage, flooding, inadequate insulation and so on. Most humidity problems are related to the fungal growth on the exterior surface, finishing material surface or hidden growth inside a gap between the exterior and interior wall (Straube and DeDraauw 2001). High levels of humidity do not affect human health. The known health effects related to high humidity are primarily caused by the growth and spread of biotic agents in elevated humidifies, although humidity interactions with non-biotic pollutants, such as formaldehyde, may also cause adverse effects. Existing limits appear to be based on engineering experience with such humidity problems in buildings. The position of upper humidity limits has greater economic significance, particularly in hot and arid parts of the country.

Most of the field and laboratory studies suggest that fungal growth does not become an issue below 70% or even 80% RH unless there are other factors influencing their growth on building surfaces. The studies conducted at lower RH values reported problems that could be corrected. In setting a maximum limit on air humidity in the space, there is little, if any evidence from field studies that provides a reason for distinguishing 60% relative humidity from 70% (Anne and Edward, 1996). Microbial growth enhanced due to greater humidity levels has been known to be a major cause of IAQ problems. In a study of 695 buildings over 10 years, microbial growth accounted for 35% of the IAQ problems encountered (Lewis et al 2001) and IEA recommended an average relative humidity of 80% as being the critical threshold. Rowan (1999) suggested a local relative humidity of 75% as a limiting fungal growth (Neil et al 1999, IEA).

Satish and William (2002) summarized that employers, by providing excellent indoor environments, hope to enhance employee comfort and productivity, reduce absenteeism and health care costs, and reduce risk of litigation. The increasing interest in this field that created additional pressure on the research community and the practical implications with regard to indoor environmental quality for architects and engineers are doing research.

III - OBJECTIVES OF THE PROJECT

The objective of this project work is to successfully develop a design of a Air Handling Unit for a HVAC System. The process is to be heat or temperature reliable, simple, cost-effective and practically feasible.

The aim of this AHU System is to provide banking to the clean room on unbanked temperature, so as to enable added cooling air on to the ducting curves in comparison to a normal air at normal temperature. This system is also supposed to enhance human comfort as the side force felt by human in a room taking a turn is comparatively less in 20°C to 25°C.

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 time in testing the integrity of each part as they have already proved their worth in real world applications.

Initially the frame design was adopted from an already existing AHU and minor changes were made to suite our purpose, the temperature first devised was based on using the input as the cooling water and lowering in each of the duct. This temperature will be later dropped in testing phase due to following disadvantages.

1. It had a very large response time; this was not suitable for an all environmental conditions.
2. Wear and tear of coils and air contact is too high to be satisfactorily used in a system.
3. The system used four high torque motors; this along with controls could shoot up the cost of production.

Due to these disadvantages, the design was dropped and a fully new design was defined. The software to be used in design is Catia V5 and testing of design is Ansys.

3.1 Summary of capabilities

Like any software it is continually being developed to include new functionality. The details below aim to outline the scope of capabilities to give an overview rather than giving specific details on the individual functionality of the product.

Catia Elements is a software application within the CAID/CAD/CAM/CAE category, along with other similar products currently on the market.

Catia Elements is a parametric, feature-based modeling architecture incorporated into a single database philosophy with advanced rule-based design capabilities.

The capabilities of the product can be split into the three main heading of Engineering Design, Analysis and Manufacturing. This data is then documented in a standard 2D production drawing or the 3D drawing standard ASME Y14.41-2003.

3.2 Engineering Design

Catia Elements offers a range of tools to enable the generation of a complete digital representation of the product being designed. In addition to the general geometry tools there is also the ability to generate geometry of other integrated design disciplines such as industrial and standard pipe work and complete wiring definitions. Tools are also available to support collaborative development.

A number of concept design tools that provide up-front Industrial Design concepts can then be used in the downstream process of engineering the product.

These range from conceptual Industrial design sketches, reverse engineering with point cloud data and comprehensive freeform surface tools.

3.3 Analysis

Ansys Elements has numerous analysis tools available and covers thermal, static, dynamic and fatigue FEA analysis along with other tools all designed to help with the development of the product. These tools include human factors, manufacturing tolerance, mould flow and design optimization. The design optimization can be used at a geometry level to obtain the optimum design dimensions and in conjunction with the FEA analysis.

IV - WORKING METHODOLOGY

For designing a proper system, it is necessary to estimate cooling load which is used to select the zone and air flow rate that the duct system distributes. Once the air flow rate is determined, the duct system component can be placed. This includes the supply and returns diffusers and decides to air handling unit (AHU) or fan coil unit is good for that space.

The air handling unit is an integrated piece of equipment consisting of fans, heating and cooling coils, air-control dampers, filters and silencers. Air Handling Units are often called AHU. The purpose of this equipment is to collect and mix outdoor air with that returning from the building space. The air mixture is then cooled or heated, after which it is discharged into the building space through a duct system made up of five-foot diameter pipes. Air Handler is normally associated with heating/cooling (HVAC) systems in commercial buildings. These are normally very large systems moving 2000 CFM to 10,000 CFM and higher. They may be mounted on the top of the roof or in large mechanical rooms located in the building. They often have an economizer or inlet damper that allows for a small amount of outside air or make-up air to be pulled in through the air handler.

4.1 General rules for design

- Air should be conveyed as directly as possible to economize on power, material and shape.
- Sudden change in direction should be avoided.
- Air velocities in ducts should be within the permissible limits to minimize losses.
- Rectangular ducts should be made as nearly square as possible. This will ensure minimum ducts surface. An aspect ratio of less than 4:1 should be maintained.
- Damper should be provided in each branch outlet for balancing the system.

Air Friction Loss

Air friction loss is affected mainly by the duct size and shape, the material used, fittings used. According to ―Carrier Handbook‖ round galvanized sheet metal has the lowest friction loss per meter, while the flexible ductwork has the highest friction loss per meter. The quality of fitting has a direct effect on the overall pressure drop of a duct system, smooth and efficient fitting with a low turbulence reduce the duct system air pressure drop. A direct route using round duct with less fitting and size changes can have a less friction loss in comparison with the similar size rectangular system with a longer route and size changes at each branch duct.

V - DESIGN METHODLOGY OF AHU

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).

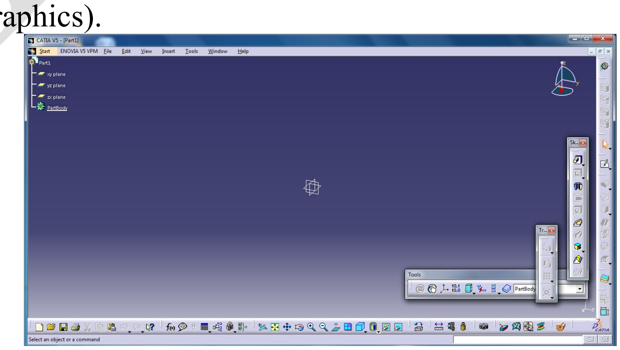

Fig: 5.1: Home Page of CatiaV5

Modeling of AHU in CATIA V5

This AHU 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.

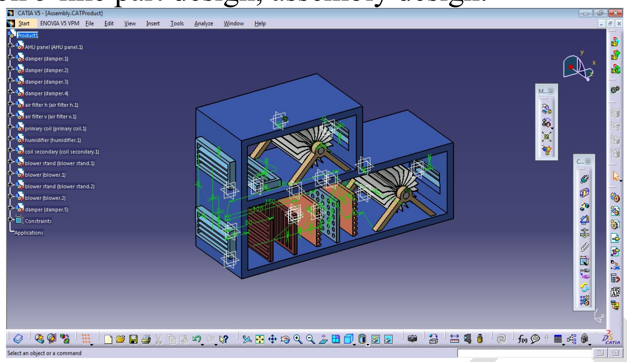

Fig: 5.2: Model design of AHU in CATIA-V5

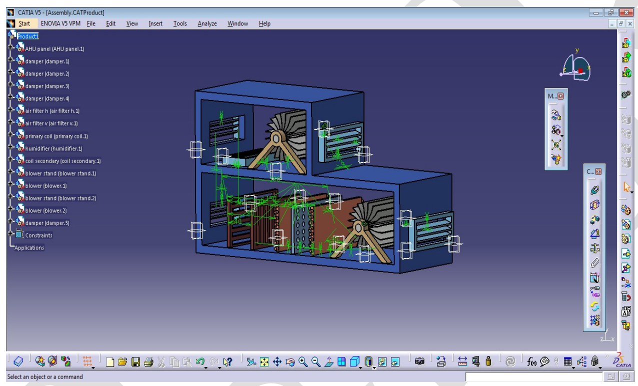

Fig: 5.3: Model arrangement in CATIA-V5

VI - ANALYSIS OF AHU

6.1 Procedure for FE Analysis Using ANSYS:

The analysis of the AHU is done using ANSYS. For compete assembly is not required, is to carried out by applying moments at the rotation location along which axis we need to mention. Fixing location is bottom legs of rod assembly machine.

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.

It is modeled with 1d element and shown as above and assembled with adjacent components. Few components are solved using Thermal Analysis for checking the stress and displacements while flowing the fluid.

VII - DISCUSSION ON ANALYSYS RESULT

7.1 Results of Nodal Temperature analysis:

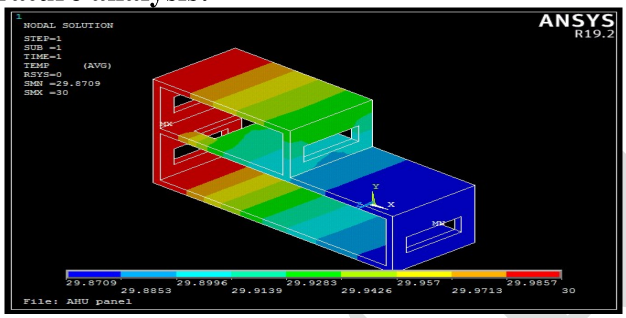

Fig: 7.1: Nodal Temperature of AHU PANNEL

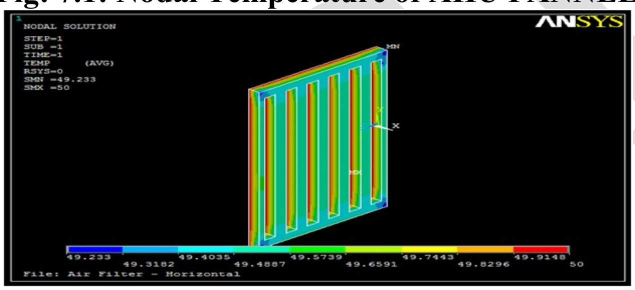

Fig: 7.2: Nodal Temperature of AIR FILTER – HORIZONTAL

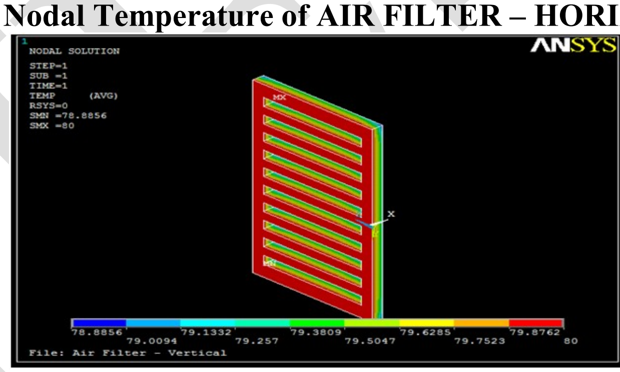

Fig: 7.3: Nodal Temperature of AIR FILTER – VERTICAL

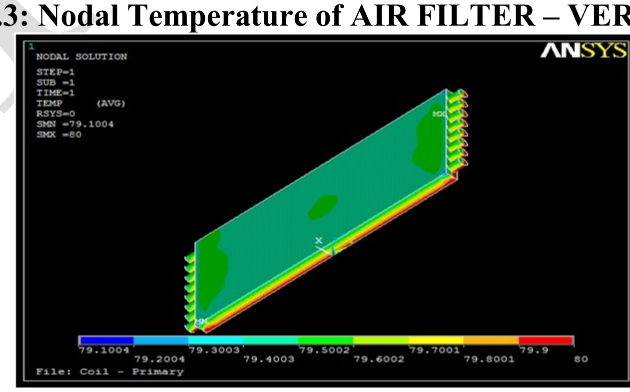

Fig: 7.4: Nodal Temperature of COIL – PRIMARY

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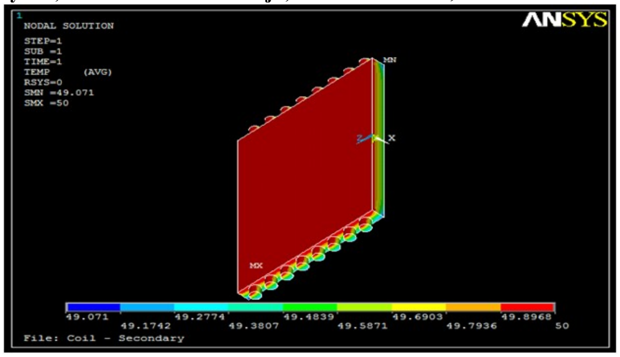

Fig: 7.5: Nodal Temperature of COIL – SECONDARY

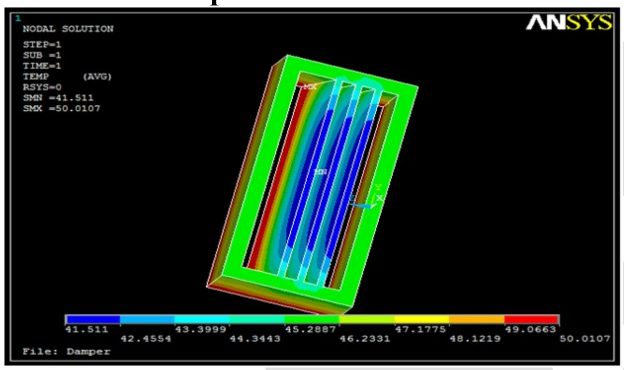

Fig: 7.6: Nodal Temperature of DAMPER

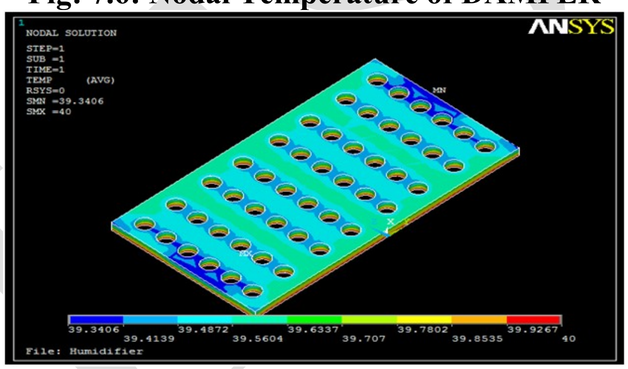

Fig: 7.7: Nodal Temperature of HUMIDIFIER

7.2 Results of Temperature Gradient analysis:

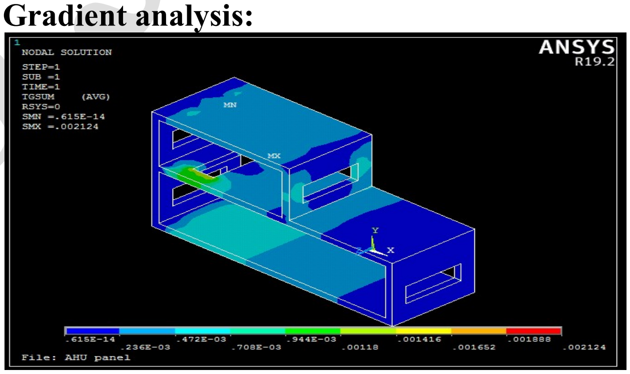

Fig: 7.8: Temperature Gradient of AHU PANNEL

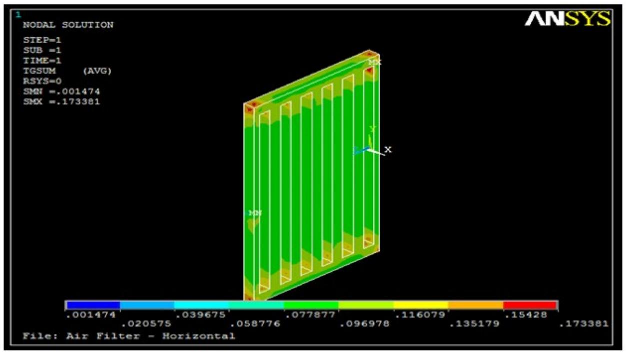

Fig: 7.9: Temperature Gradient of AIR FILTER – HORIZONTAL

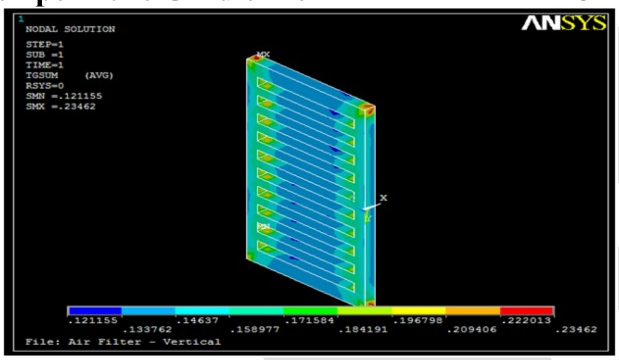

Fig: 7.10: Temperature Gradient of AIR FILTER – VERTICAL

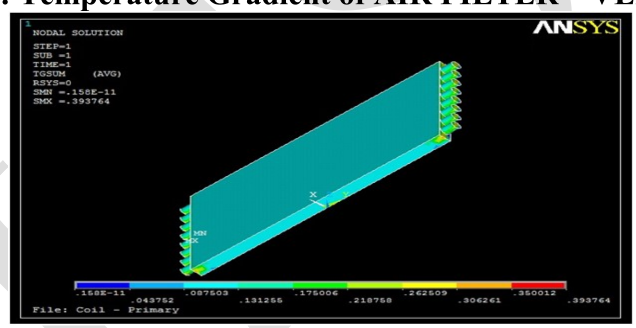

Fig: 7.11: Temperature Gradient of COIL – PRIMARY

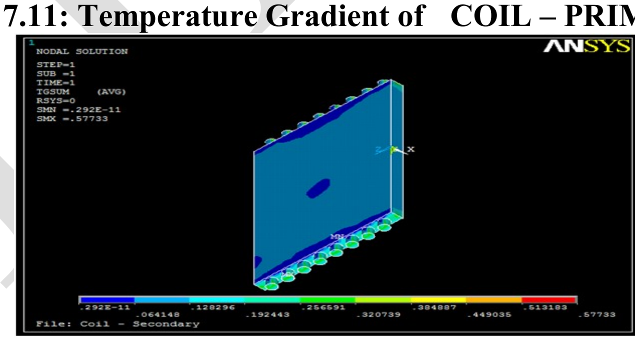

Fig: 7.12: Temperature Gradient of COIL – SECONDARY

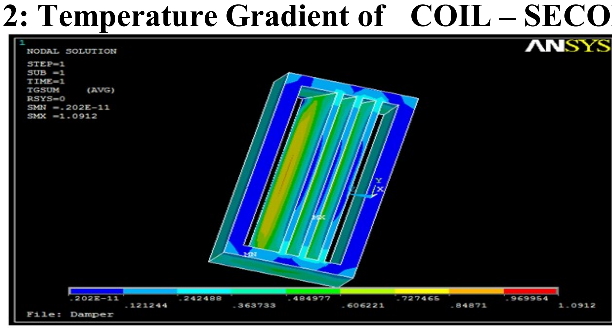

Fig: 7.13: Temperature Gradient of DAMPER

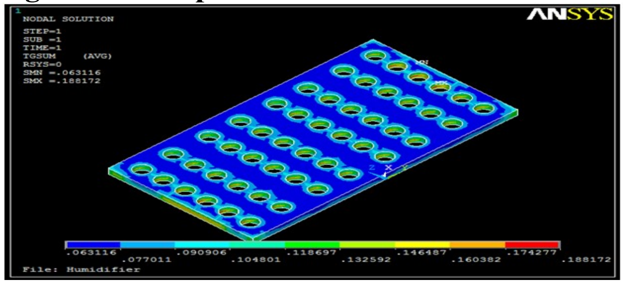

Fig: 7.14: Temperature Gradient of HUMIDIFIER

6.3 Results of Thermal Flux analysis:

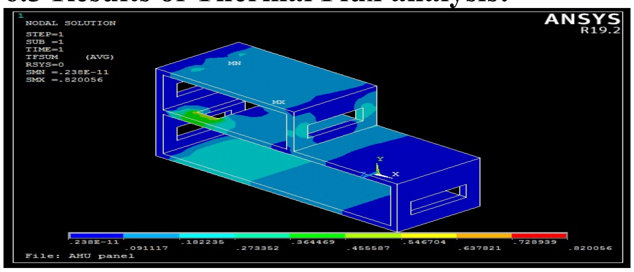

Fig: 7.15: Thermal Flux of AHU PANNEL

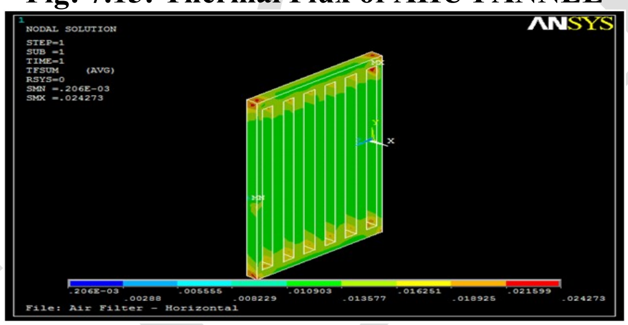

Fig: 7.16: Thermal Flux of AIR FILTER – HORIZONTAL

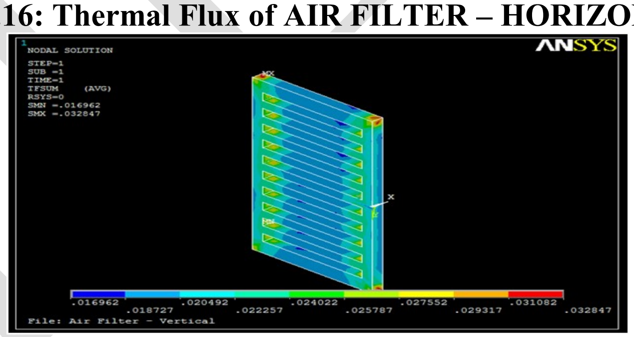

Fig: 7.17: Thermal Flux of AIR FILTER – VERTICAL

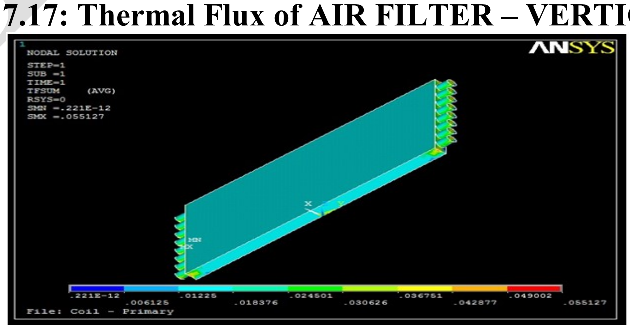

Fig: 7.18: Thermal Flux of COIL – PRIMARY

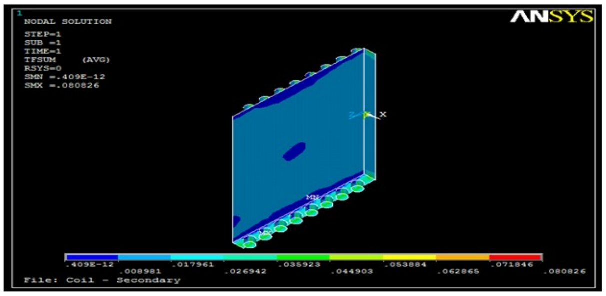

Fig: 7.19: Thermal Flux of COIL – SECONDARY

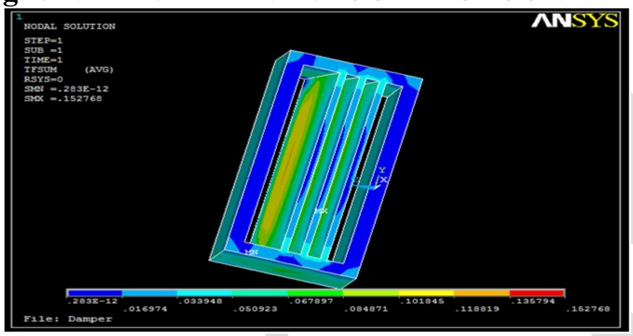

Fig: 7.20: Thermal Flux of DAMPER

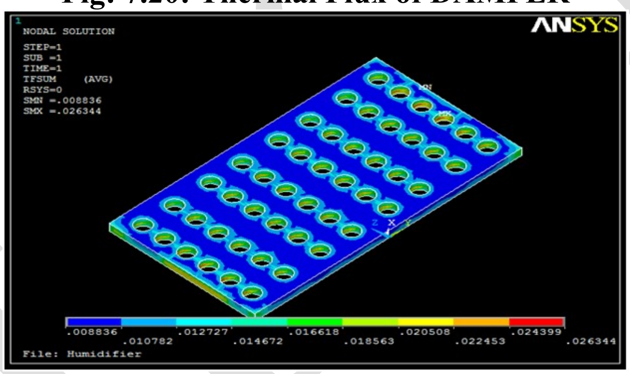

Fig: 7.21: Thermal Flux of HUMIDIFIER

6.4 Results of Heat Flow analysis:

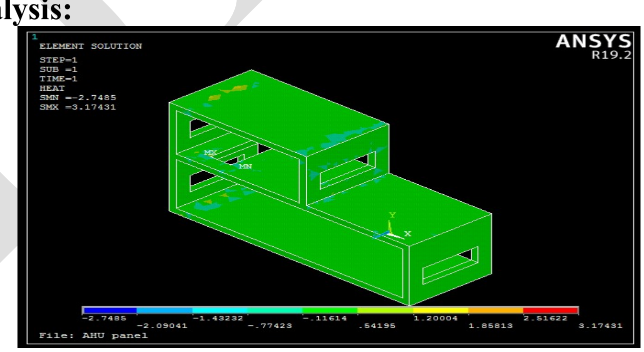

Fig: 7.22: Heat Flow of AHU PANNEL

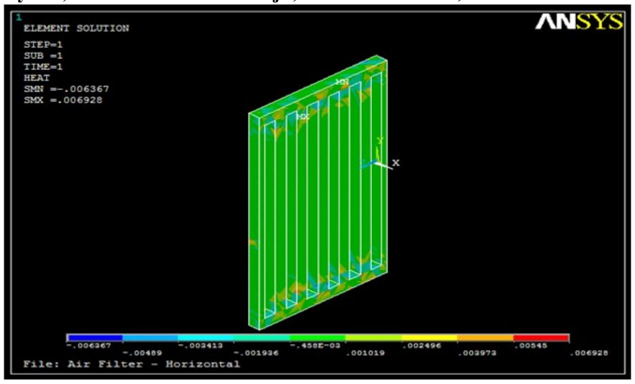

Fig: 7.23: Heat Flow of AIR FILTER – HORIZONTAL

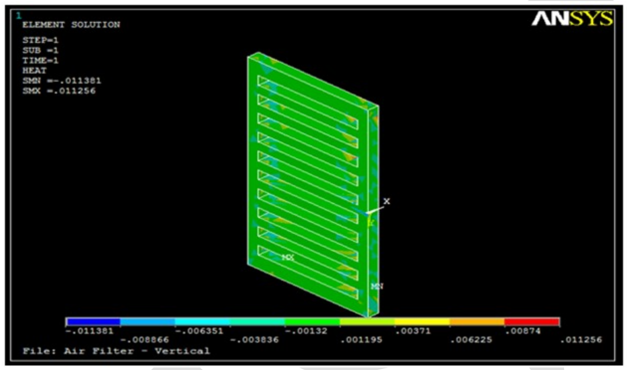

Fig: 7.24: Heat Flow of AIR FILTER – VERTICAL

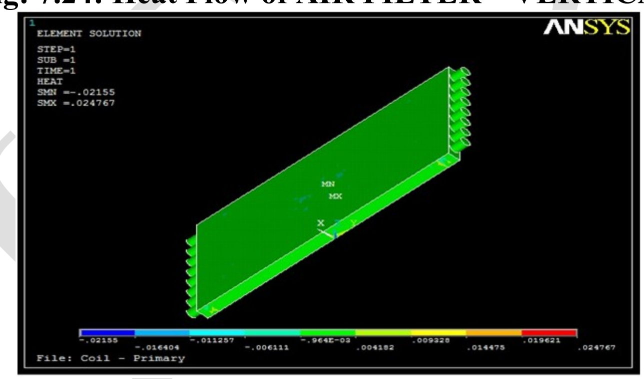

Fig: 7.25: Heat Flow of COIL – PRIMARY

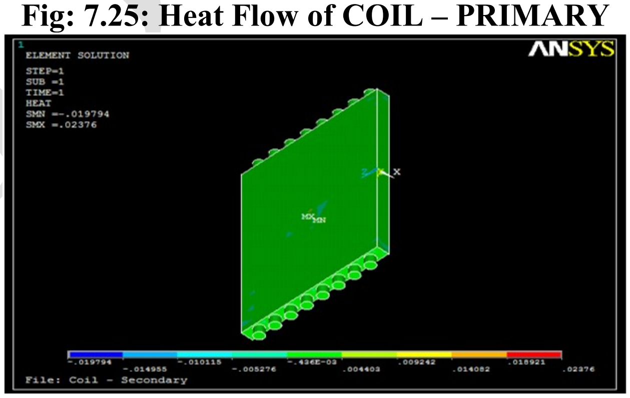

Fig: 7.26: Heat Flow of COIL – SECONDARY

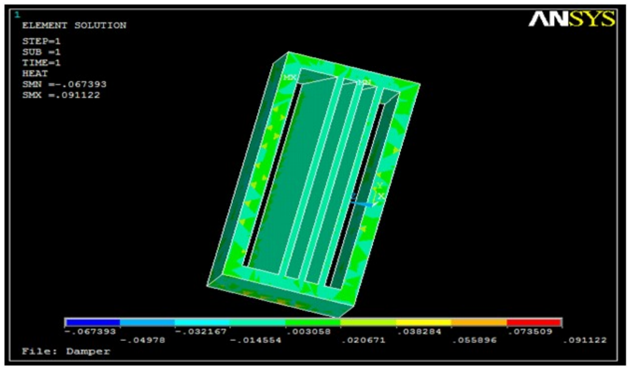

Fig: 7.27: Heat Flow of DAMPER

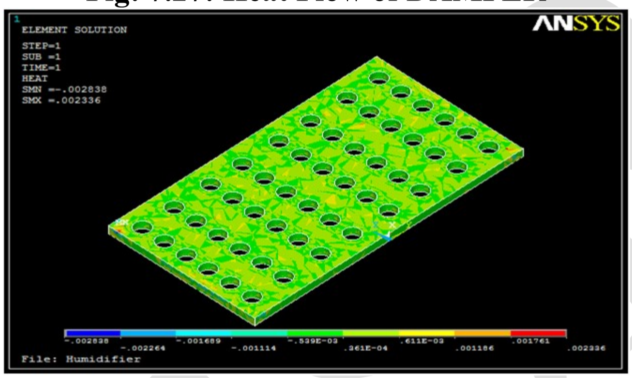

Fig: 7.28: Heat Flow of HUMIDIFIER

VIII - CONCLUSION

It can be seen from the above results that, our objective to manipulate the temperature of an AHU in a HVAC System has been successful. As shown above figures the temperature of the air is a complete design assembly is manipulated and reached as per the requirement and solved using Ansys and temperature convection is 29.87°C in AHU system. This is showing us that clearly each component in its thermal analysis.

Thermal Flux is at the location. The value is 0.82 which is very less compared to yield value. The maximum heat flow is 3.174 coming, this solution solving with the help of Ansys software so that the maximum thermal gradient is 0.0021. So we can conclude our design parameters are approximately correct.

After studying above, the results comes that circular duct has minimum friction loss as compared to the rectangular duct. The design of the Air Handling Unit worked flawlessly in analysis as well, all these facts point to the completion of our objective in high esteem.

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