Thermal Analysis of Solar Air Heater Using CFD as A Tool

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ABSTRACT: Solar air heating is a solar thermal technology in which the energy from the sun is captured by an absorbing medium and used to heat air. Solar air heater including a housing having a transparent front wall and an inlet and outlet for establishing a flow path for a gas such as air to be heated. An attempt has been made to carry out CFD based analysis using FLUENT to fluid flow and heat transfer characteristics of solar air heater. 3D model of the Solar Air heater involving air inlet, absorber plate, glass, modeled by ANSYS Workbench and the unstructured grid was created in ANSYS. The results were obtained by using ANSYS FLUENT software. This work is done by using computational fluid dynamics (CFD) tool with respect to flow and temperature distribution inside the solar air heater.

Key words: CFD, Ansys, AH, Tool, Solar air heating

I. INTRODUCTION

Solar air heating is a solar thermal technology in which the energy from the sun, insolation, is captured by an absorbing medium and used to heat air. Solar air heating is a renewable energy heating technology used to heat or condition air for buildings or process heat applications. It is typically the most cost-effective out of all the solar technologies, especially in commercial and industrial applications, and it addresses the largest usage of building energy in heating climates, which is space heating and industrial process heating.

HISTORY OF AIR HEATING:

For the first 100 years home heating was dominated by biomass (wood) and it was not until 1885 that the nation would burn more coal than wood. Prior to 1885 the majority of homes were heated with wood burning brick fireplaces and derivatives of the cast iron Franklin stove invented in 1742.

By the end of the 19th century the invention of low-cost cast-iron radiators would bring central heating to homes with a coal fired boiler in the basement delivering hot water or steam to radiators in every room. At about the same time, in 1885, Dave Lennox built and marketing the industry's first riveted-steel coal furnace. Without electricity and fans to move air, these early furnaces transported heat by natural convection (warm heated air rising) through ducts from the basement furnace to the rooms above. These two methods would dominate home central heating until 1935, when the introduction of the first forced air furnace using coal as a heat source used the power of an electric fan to distribute the heated air through ductwork within the home.

Shortly thereafter, gas and oil-fired versions of forced air furnaces would relieve the homeowners from the chore of "stoking the coal fire" and relegate coal furnaces and cast-iron radiators to the dust bin of history. Fast forward to today and about 60% of our homes be heated with gas fired forced air furnaces (FAU's) and another 9% with oil fired FAU's. In warmer climates, a quarter of our homes would be heated by FAU's using electric "heat pumps" to supply heating energy.

MODERN BEGINNINGS:

Chimneys and Stoves: -

The next important advance in heating was the invention of the chimney. The origins of the chimney flue probably lie with the Normans, who used sidewall flue openings in place of the previously used central roof vents. Many sidewall flues were constructed at an oblique angle upward, thus beginning a transition to vertical chimney construction.

After the 14th century, chimneys appear in written literature. However, their use seems to have spread very slowly. Chimneys were still rare enough 200 years later that one Early chimneys were very large, so as to allow a chimney sweep to climb into them. But the size precipitated such vicious drafts that room divider screens sometimes had to be used to shield the occupants.

Stove heating soon advanced beyond the crude devices first used. The first freestanding warm-air stove was probably the "Furnus Acapnos" or "smokeless stove" invented by Dalesme in France in the late 1600s. Dalesme introduced fresh fuel in the same opening as combustion air, directing

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all combustion products over already-burning fuel, a design that ensured complete combustion.

Although the smokeless stove was a great advance, it and other heating innovations were accepted slowly, for "…few housekeepers are philosophers enough to be willing to undertake the management of a machine requiring especial mental effort, where the advantages are not directly visible to the senses."

The earliest stove in North America was probably a cast iron box stove invented by Dr. John Clarke of the Massachusetts Bay Colony about 1652. This type of stove had originated in Holland and was imported into England after 1600. By the mid-1700s, cast iron box stoves were being manufactured by a number of eastern Colonial American foundries.

Stoves continued evolving throughout the 1800s. Notable improvements included the base burner stove invented by Eliphalet Knott in 1833, and the airtight stove invented by Isaac Orr in 1836.

A stove with thermostatic draft control was invented by F.P. Oliver in 1849.

By the time of the Civil War, cast iron stove manufacturing was a large and well-established industry, particularly in the north-eastern U.S. By 1900, thousands of different designs (many approaching pieces of art in their appearance) were produced by dozens of manufacturers.

SOLAR ENERGY

Solar energy is the most readily available source of energy. It does not belong to anybody and is, therefore, free. It is also the most important of the non-conventional sources of energy because it is non-polluting and, therefore, helps in lessening the greenhouse effect.

Solar energy has been used since prehistoric times, but in a most primitive manner. Before 1970, some research and development was carried out in a few countries to exploit solar energy more efficiently, but most of this work remained mainly academic. After the dramatic rise in oil prices in the 1970s, several countries began to formulate extensive research and development programmes to exploit solar energy. When we hang out our clothes to dry in the sun, we use the energy of the sun. In the same way, solar panels absorb the energy of the sun to provide heat for cooking and for heating water. Such systems are available in the market and are being used in homes and factories.

PARAMETERS FOR STUDY:

1. Analysis of existing design and New Design
2. Analysis of Final Proposed Design
3. Optimization of Final Design
4. Fabrication of Final Design

TOOL USED:

Finite Element Analysis

The useful features of finite element Analysis are as follows:

1. Discretization of the whole model into small elements, which may be square, rectangle, and triangle or in polygon shapes.
2. Derive the governing differential equations for each element of the model.
3. Assembly of all elements, based on stability of the solution.

DESIGN MODELER:

Autodesk Inventor 2015

1. Autodesk Inventor was introduced in 1999 as an ambitious 3D parametric modeler based not on the familiar AutoCAD programming architecture but instead on a separate foundation that would provide the room needed to grow into the fully featured modeler it now is, a decade later.
2. Inventor 2015 continues the development of Inventor with assembly layout, plastic parts, and other productivity tools.
3. The maturity of the Inventor tools coincides with the advancement of the CAD market's adoption of 3D parametric modelers as a primary design tool.

ANALYSIS SOFTWARE:

ANSYS Mechanical workbench

ANSYS is a complete FEA software package used by engineers worldwide in virtually all fields of engineering:

1. Structural
2. Thermal
3. Fluid, including CFD (Computational Fluid Dynamics)
4. Electrical / Electrostatics
5. Electromagnetic

PARTIAL LIST OF INDUSTRIES IN WHICH ANSYS IS USED:

1. Aerospace
2. Automotive
3. Biomedical
4. Bridges & Buildings
5. Electronics & Appliances
6. Heavy Equipment & Machinery
7. MEMS - Micro Electromechanical Systems
8. Sporting Goods

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II. RESULTS OBTAINED

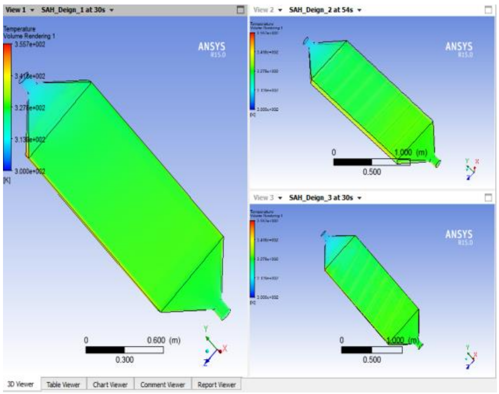

Fig. 1 Result

A Three- dimensional Computational fluid dynamics (CFD) analysis has been carried out to study heat transfer behavior in a rectangular duct of solar air heater having plain surface and artificial roughness. Three surfaces are taken into consideration: plain surface, normal zig zag surface and inclined zig zag surface. By the CFD analysis, we found that efficiency of solar air heater with plain surface rectangular duct is more than the solar air heater with normal zig zag and inclined zig zag surface. It can be seen from fig. that the enhancement in heat transfer of the abnormal duct with respect to the smooth duct is less.

SI.NO	Surface	Temperature
1	Plain surface	3.542 e+002
2	Normal Zig zag surface	3.557e+002
3	Inclined zig zag surface	3.553e+002

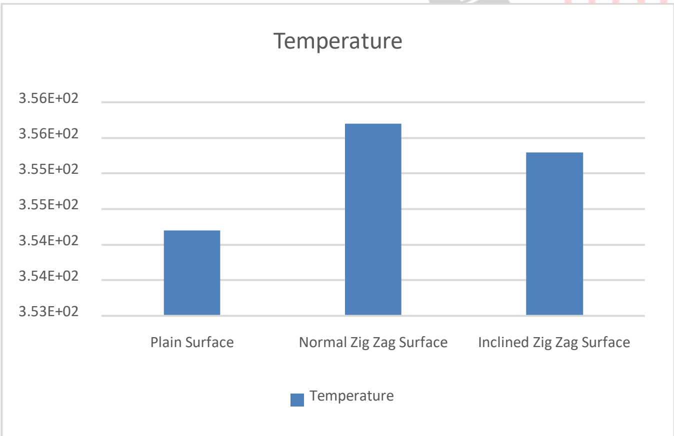

Fig 2: Differentiation between different surfaces

TYPES OF APPLICATIONS FOR SOLAR AIR HEATING ARE NUMEROUS:

Production plants, factories, workshops, warehouses, exhibition halls, offices, institutional facilities, theatres, gymnasiums, dryers, cleaners. The right solar heating product will perform best if properly integrated within the HVAC and control system of the building.

SOLAR AIR HEATING CONNECTED TO THE MAKE-UP AIR UNIT:-

This application is the most common. The solar air collector is mounted upstream of the make-up air unit, preheating the air before it reaches the burner. Even on cloudy winter days, a relatively low temperature rise of 5C will result in fuel and money savings.This set-up is to be used preferably if the operating hours of the unit are over 6 hours per day, 5 days a week.

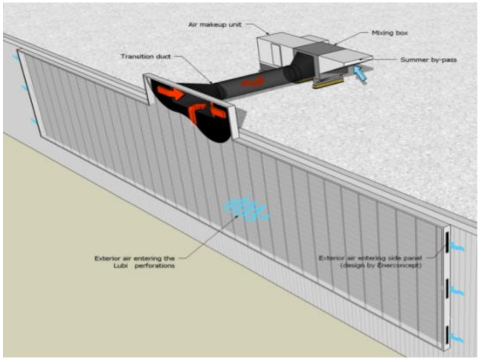

Fig 3: SAH connected to the make up air unit

SOLAR AIR HEATING IN PARALLEL WITH THE MAKE-UP AIR UNIT: -

In this application, the fan pulls in outside air through the solar collectors and mixes it with inside, with interlocked mixing dampers, so that air is delivered at a constant supply temperature inside the building. As a result, outside air flow may vary depending on sunshine and weather conditions. Advantages of this configuration include:

- Solar gains at all times, even during unoccupied periods (week-ends)
- Mechanically independent of the gas-fired make-up air unit
- Linked with other HVAC components via automated controls
- Oxygen-rich heated fresh air supply (as opposed to fuel gas from direct-fired units)

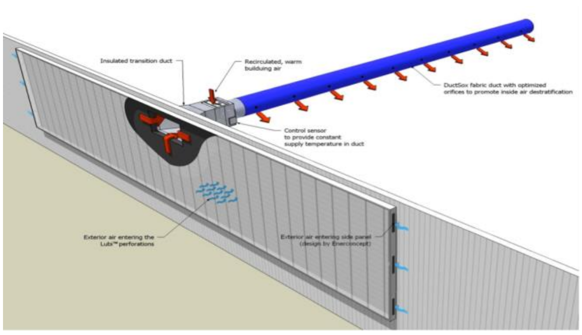

Fig 4: SAH in parallel with the makeup air unit

This configuration is generally used if the gas-fired unit works irregularly, upon gas detection (alarm) or if the make-up air unit cannot easily de ducted to the solar air heater.

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SOLAR AIR HEATING WITHIN LOOP OF ROOF-TOP UNIT: -

Thanks to our line of roof mounted solar panels which deliver heat even in the coldest conditions, preheat the air before it reaches the ventilation unit.

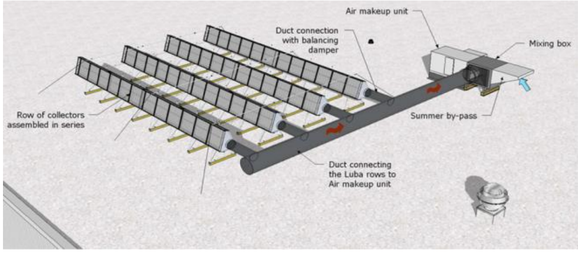

Fig 5: SAH within loop of roof top unit

III. CONCLUSIONS

A Three- dimensional Computational fluid dynamics (CFD) analysis has been carried out to study heat transfer behavior in a rectangular duct of solar air heater having artificial roughness. There is a good agreement between the experimental and simulated results for outlet air temperatures. The Nusselt number of CFD results has maximum ±8.73 % over experimental results. In this present investigation, a prediction has been conducted to study heat transfer behaviors of a rectangular duct of a solar air heater having plain surface and artificial roughness on the absorber plate. The main conclusions are:

1. There is no doubt that a major focus of CFD analysis of solar air heater is to enhance the design process that deals with the heat transfer and fluid flow.

2. In recent years CFD has been applied in the design of solar air heater. The quality of the solutions obtained from CFD simulations are largely within the acceptable range proving that CFD is an effective tool for predicting the behavior and performance of a solar air heater.

3. Solar air heater with plain surface have better efficiency of heat transfer as compared to abnormal surface.

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