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A CFD BASED HEAT TRANSFER AND FLUID FLOW ANALYSIS OF SOLAR AIR HEATER PROVIDED WITH COMBINATION OF CIRCULAR AND SQUARE SECTION TRANSVERSE RIB ROUGHNESS ON THE ABSORBER PLATE

Ajeet Singh Kushawaha[1], Ravi Vishwakarma[2]

[1] Research Scholar, [2] Professor, Shri Institute of Science &Technology, RGPV Bhopal, MP, (India)

ABSTRACT

The study of heat transfer and fluid flow processes in an artificially roughened solar air heater by using computational fluid dynamics (CFD). The effects of small diameter of circular and square transverse wire rib roughness on heat transfer and fluid flow have been investigated. The Reynolds number, relative roughness pitches (P/e) and relative roughness height (e/D) are chosen as design variables. A 3-D CFD simulation is performed using the ANSYS FLUENT 14.5 code. The Renormalization-group (RNG) k-ε model is selected as the most appropriate one. Results are validated by comparing with available experimental results. It is apparent that the turbulence created by small diameter of transverse wire ribs result in greater increase in heat transfer over the duct. However, the use of artificial roughness results in higher friction losses. The present CFD investigation clearly demonstrates that the average Nusselt number and average friction factor increase with increase in the relative roughness height. The condition for optimum performance has been determined in term of thermal enhancement factor1.39. A maximum value of heat transfer coefficient has been found to be 31.6467 for the range of parameters investigated.

Keyword: Solar Air Heater, Reynolds's number, Heat Transfer Rate, Thermal Enhancement Factor, CFD.

I. INTRODUCTION

Heat transfer enhancement is a subject of considerable interest to researchers as it leads to saving in energy and cost. Because of the rapid increase in energy demand in all over The world, both reducing energy lost related with ineffective use and enhancement of energy in the meaning of heat have become an increasingly significance task for design and operation engineers for many system. In the past few decades numerous researches have been performed on heat transfer enhancement. These researches focused on finding a technique not only increasing heat transfer, but also achieving high efficiency. Achieving higher heat transfer rates through various enhancement techniques can result in substantial energy saving, more compact and less expensive equipment with higher thermal efficiency. Heat transfers enhancement technology has been improved and widely used in heat exchanger application; such as refrigeration, automotives, process industry, chemical industry, etc. One of the widely-used heat transfer enhancement technique is inserting different shaped elements with different geometries in channel flow.

1.1 Renewable Energy Scenario in India

India is blessed with an abundance of sunlight, water and biomass. Vigorous efforts during the past two decades are now bearing fruit as people in all works of life are more aware of the benefits of renewable energy, especially decentralized energy where required in villages and in urban or semi-urban centers. India has the world's largest programmed for renewable energy. Government created the Department of Non-conventional Energy Sources (DNES) in 1982.

Energy is defined as the ability or the capacity to do work. Energy is the basic ingredient to sustain life and development. Work means moving or lifting something, warming or lighting something. There are many sources of energy that help to run the various machines invented by man. There has been an enormous increase in the demand for energy since the middle of the last century as a result of industrial development and population growth. World population grew 3.2 times between 1850 and 1970, per capita use of industrial energy increased about twenty fold, and total world use of industrial and traditional energy forms combined increased more than twelve fold.

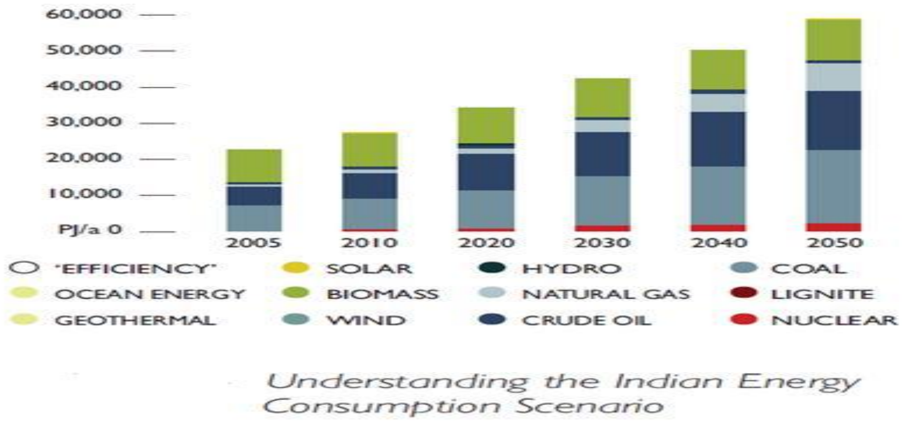

Figure 1: Energy Consumption in India

1.2 Solar Thermal Energy

Solar Thermal energy is heat energy obtained by exposing a collecting device to the rays of the sun. A solar thermal energy system makes use of the warmth absorbed by the collector to heat water or another working fluid or to make steam.

Advantages:

1. Solar Thermal Energy makes use of renewable natural resources which is readily available in most parts of the world.
2. Solar energy used by it creates no CO_2 or other toxic emission.
3. The heated fluid can be stored in insulated tanks allowing energy to be used during brief cloudy overcast periods.

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Disadvantages:

1. Solar Thermal Energy system is not cost-effective in areas which have long periods of cloudy weather or short daylights.
2. In cooler climates freezing can damages collecting system components.

The components of solar air heater are:-

(i) Transparent glass cover.

(ii) Absorber plate or heated wall.

(iii) Insulation bottom.

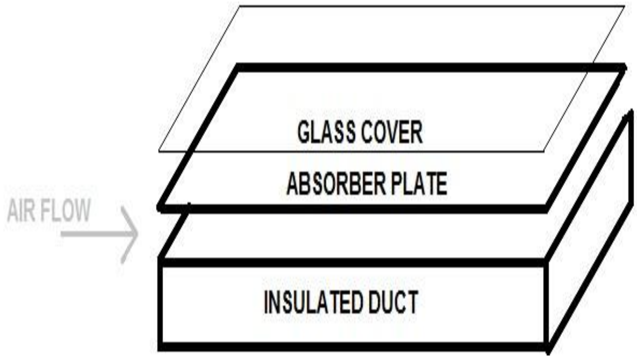

Figure 2: Concept of Solar Air Heater

II. EXPERIMENTAL SETUP

Figure 3: Experimental Setup

III. PROBLEM FORMULATION ANALYSIS

To make solar air heater more efficient there is in need of increase in heat transfer capability in SAH duct which can be done by creating turbulence in a duct by introducing artificial roughness geometry in it. Basically artificially roughened absorber plate breaks the laminar sub-layer in order to reduce thermal resistance and increase heat transfer coefficient. Artificially roughness geometry on underside of an absorber surface is an effective technique to enhance heat transfer and fluid flowing in a rectangular duct of SAH. The application of artificial roughness geometry (in different shapes) has been recommended to enhance the heat transfer coefficient by several investigators. Till date many researchers have used various artificial roughness geometry plates in SAH duct to enhance its performance. Various roughness plate used are Transverse wedge shaped rib, metal grit ribs, dimple ribs, inclined with gap ribs, multi v-shaped ribs, arc shaped ribs, protruded roughness geometry, W-shaped ribs , circular ,square ribs etc.

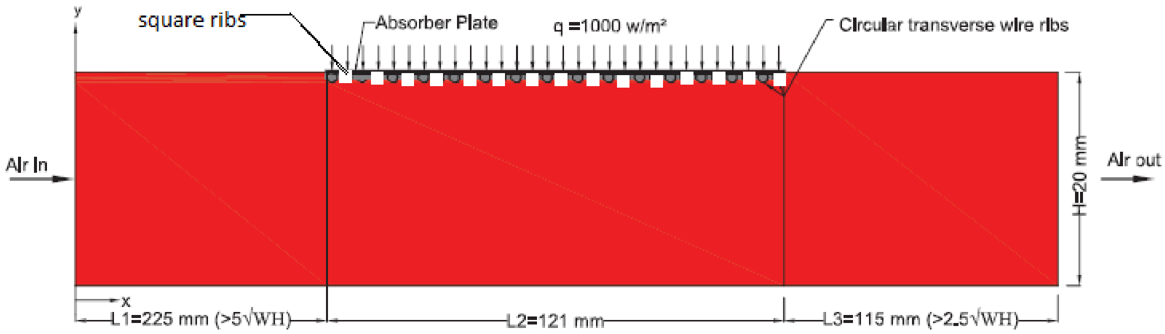

Figure 4: Computational Domain for Solar Air Heater

IV. METHODOLOGY

Computational fluid dynamics (CFD) is a computer-based simulation method for analyzing fluid flow, heat transfer, and related phenomena such as chemical reactions.

This project uses CFD for analysis of flow and heat transfer. Some examples of application areas are: aerodynamic lift and drag (i.e. airplanes or windmill wings), power plant combustion, chemical processes, heating/ventilation, and even biomedical engineering (simulating blood flow through arteries and veins).

CFD analyses carried out in the various industries are used in R&D and manufacture of aircraft, combustion engines, as well as many other industrial products.

It can be advantageous to use CFD over traditional experimental-based analyses, since experiments have a cost directly proportional to the number of configurations desired for testing, unlike with CFD, where large amounts of results can be produced at practically no added expense. In this way, parametric studies to optimize equipment are very inexpensive with CFD when compared to experiments.

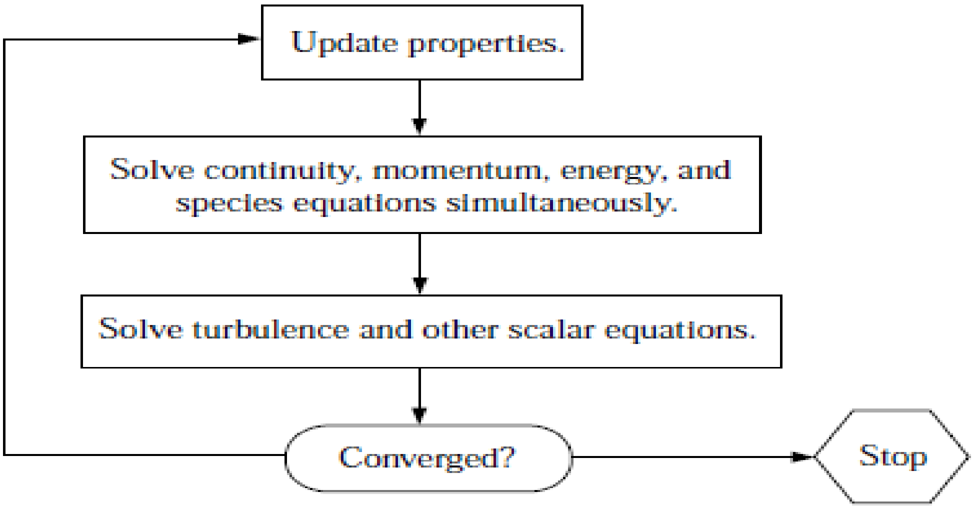

Figure 5: Over view on the COUPLED Solution method

V.RESULT AND DISCUSSION

This chapter presents the predicted airflow velocity, pressure and temperature profiles during Forced-air flow over rib geometry in the duct which were consider in this research work. The CFD analysis has been performed for combination of circular and square ribs on absorber plat of SAH and result has been compared with the case of smooth duct operating under the same Conditions to evaluate the enhancement in heat transfer.

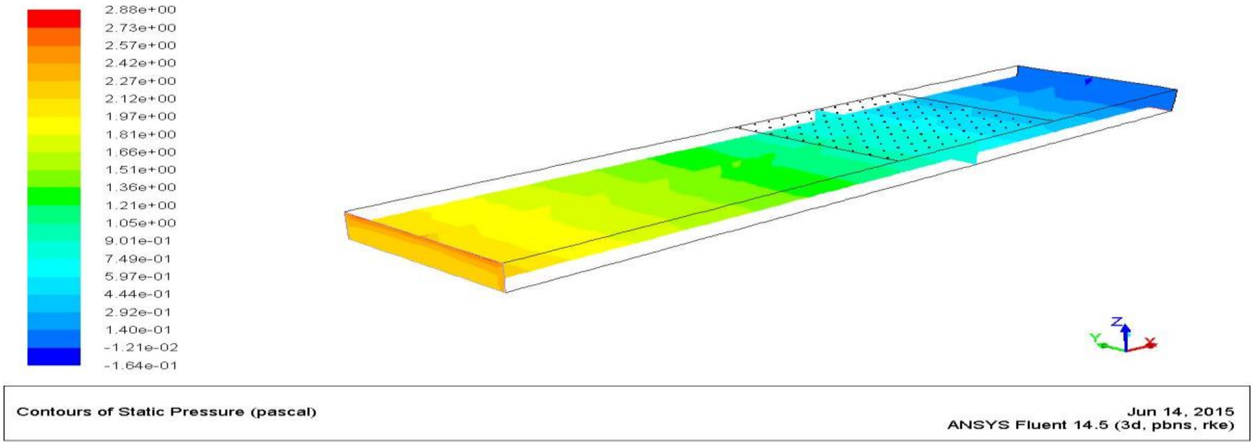

Fig.6 Plate-square-circular-p10-e-0.5-re-5000-pressure

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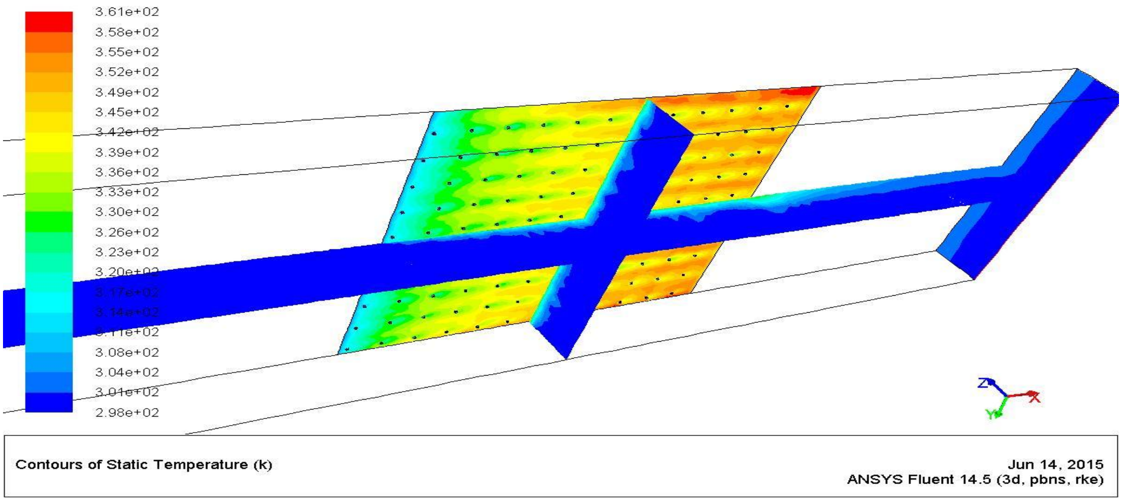

Fig.7 Plate-Square-Circular-p10-e-0.5-re-5000-Tempreture

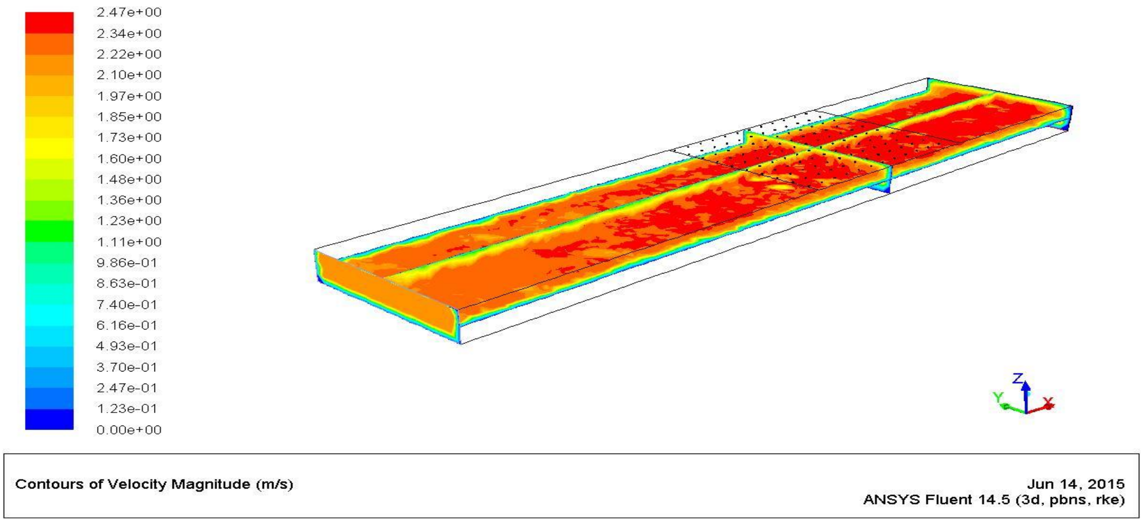

Fig.8 Plate-Square-Circular-p10-e-0.5-re-5000-Velocity

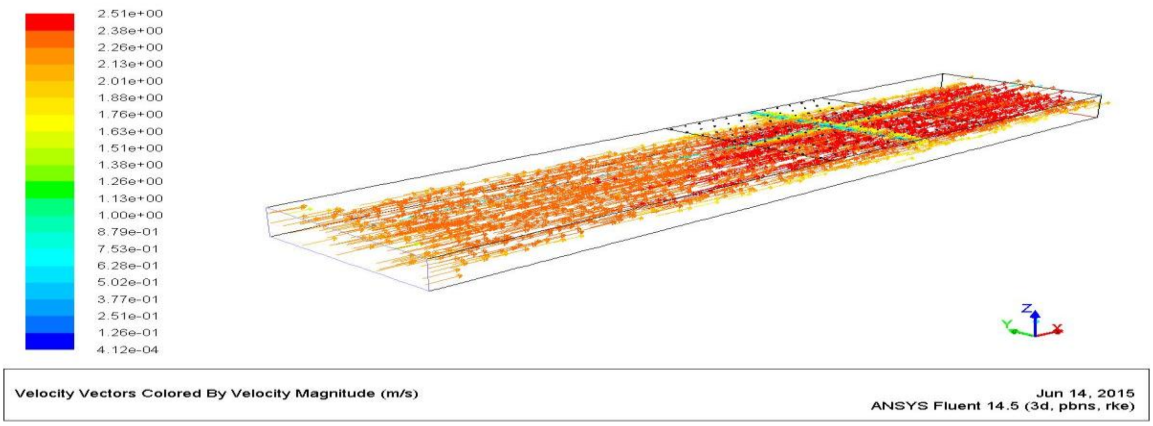

Fig.9 Plate-Square-Circular-p10-e-0.5-re-5000-Velocity Vector

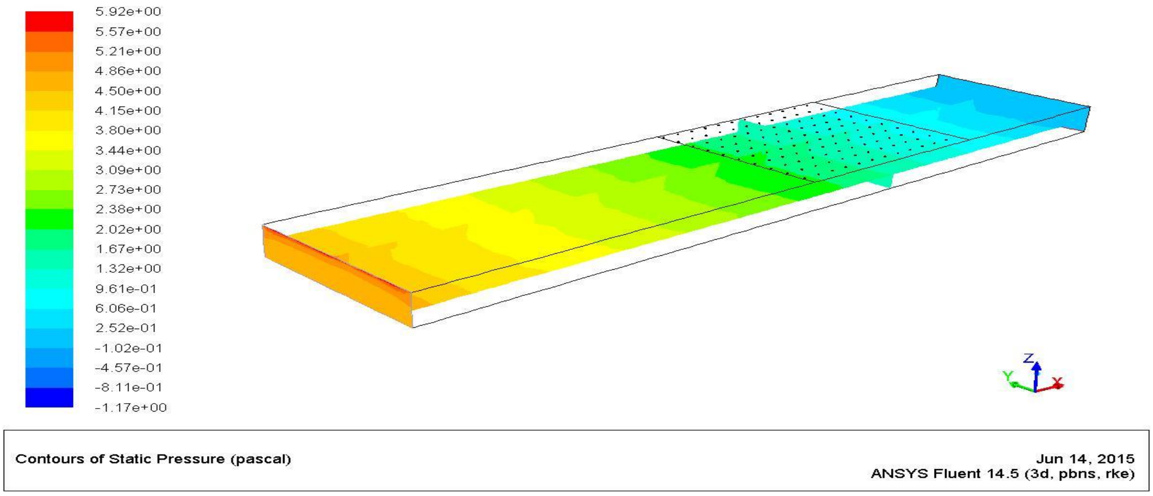

Fig.10 Plate-sq-circ-p10-e-0.5-re-8000-Pressure

VI. CONCLUSION

A 3-dimensional CFD analysis has been carried out to study heat transfer and fluid flow behavior in a rectangular duct of a solar air heater with one roughened wall having combination of circular

And square transverse wire rib roughness. The effect of Reynolds number, roughness height, roughness pitch, relative roughness pitch and relative roughness height on the heat transfer coefficient and friction factor have been studied. In order to validate the present numerical model, results have been compared with available experimental results under similar flow conditions. CFD Investigation has been carried out in medium Reynolds number flow (Re ¼3800e18, 000). The following conclusions are drawn from present analysis:

1. The Renormalization-group (RNG) k-ε turbulence model predicted very close results to the experimental results, which yields confidence in the predictions done by CFD analysis in the present study. RNG k-ε turbulence model has been validated for smooth duct and grid independence test has also been conducted to check the variation with increasing number of cells.

2. Average Nusselt number increases with an increase of Reynolds number. The maximum value of average Nusselt number is found to be 43.577 for relative roughness pitch of 5 and for relative roughness height of 0.06 at a higher Reynolds number, 10,000.

3. Average friction factor decreases with an increase of Reynolds number. The maximum value of average friction factor is found to be 1.698 for relative roughness pitch of 5 and relative roughness height of 0.06 at a lower Reynolds number, 5000.

4. It is found that the circular and square transverse wire rib roughness with P/e ¼ 5 and e/D ¼ 0.06 provides better thermal enhancement factor for the studied range of Reynolds number and hence can be employed for heat transfer augmentation.

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