"Numerical Analysis on Laminar Flow Forced Convection on a channel with upper V-corrugated Plate heated by Radiation on CFD."

Harshad A. Gangapurwar[1], Sahil P. Balpande[2], Vaibhav V. Nikose[3], Anup S. Saudagar[4], Ankit S. Patil[5], Dr. S .V. Prayagi[6]

[1,2,3,4,5]Students, Dr. Babasaheb Ambedkar College of Engineering & Research, Nagpur
[6]Professor, Dr. Babasaheb Ambedkar College of Engineering & Research, Nagpur

---

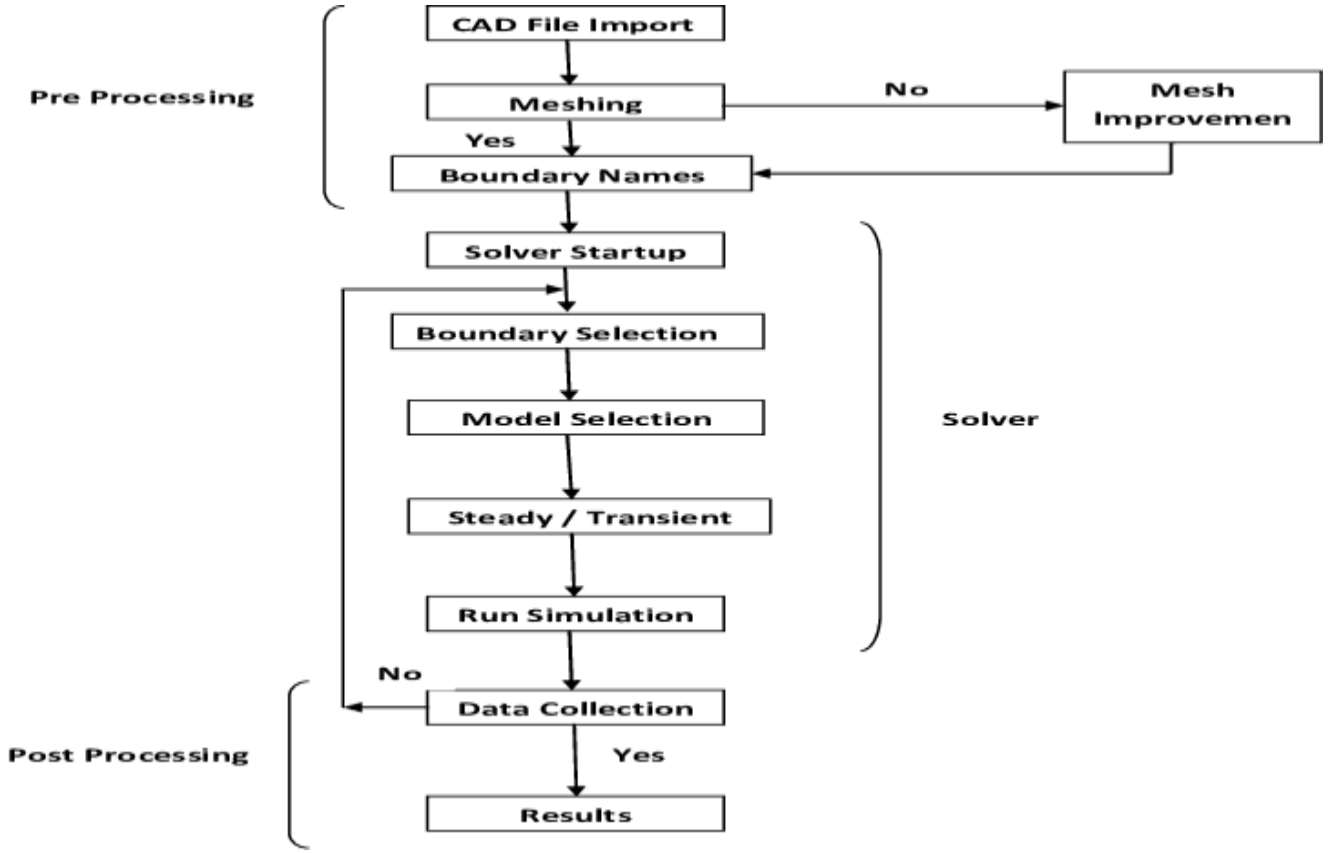
Abstract: Numerical study of the effects of the operating parameters on laminar flow forced-convection heat transfer for air flowing in a channel having a V-corrugated upper plate heated by radiation heat flux while the other walls are thermally insulated has been carried out. The parameters studied and their ranges were as follows: flow Reynolds number (R_e) ranging from 750 to 2050, incident radiation fluxes (q_{inc}) of 400, 700, and 1000 W/m^2, inlet air bulk temperatures ($T_{b,in}$) ranging from 12 to 60^0 C. The results show that, the effect of R_e on local Nusselt number (Nu) are clear and more significant at the channel entrance region. While, changing the value of R_e leads to an increase in Nu_x by a ratio ranging depending on Re values and other operating parameters. In addition, the results indicate that there are significant increases in Nu_x in the channel entrance region due to the increase in inlet air bulk temperature.

Index Terms: Heat transfer augmentation, CFD, Nusselt number, Reynolds number, convective heat transfer coefficient

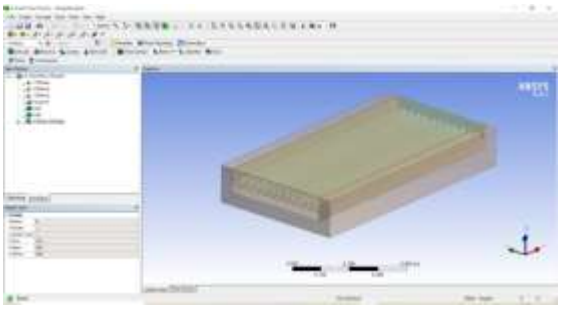
Introduction:

Characteristics of laminar flow forced-convection heat transfer for air flowing in a channel having a V-corrugated upper plate heated by radiation heat flux and thermally insulated flat sidewalls and bottom is an important subject for air heater solar collectors applications. Conventional heat exchangers are known to accomplish a fluid-to-fluid heat exchange with radiation as a negligible factor, while solar air heater collectors, which are special types of heat exchangers, use solar radiation to heat the air (working fluid). However, because of the low thermal and hydrodynamic properties of the air, solar air collectors have the disadvantage of low convective heat transfer coefficient compared with those that use liquids as working fluids. As the result concluded by [1], The use of a V-corrugated plate as an absorber in a solar air collector improves its thermal performance for two reasons. First, corrugations enhance the convective heat transfer coefficient (h) and at the same time the effective convective heat transfer area (A) increases, resulting in a collective increase of the convective conductance (hA). The second reason is that, the V-corrugated plate absorber provides an apparent absorptivity to the incident radiation flux of almost unity even when painted with commercial black paint. The aim of this work is to study numerically the effects of different operating parameters on the convective heat transfer coefficient in laminar flow, for the suggested channel configuration which is formed by an upper V-corrugated plate heated by radiation flux and thermally insulated flat sides and bottom. The operating factors studied are the incident radiation heat flux, Reynolds number, inlet air bulk temperature.

Methodology:

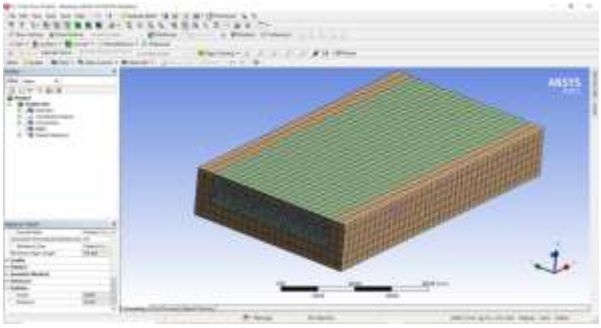


GEOMETRY MODELING: First the geometry of the model is created in CATIA. The model is saved in CATIA part type file i.e.(.CATPart).The external geometry file is imported in the design modeler of the ANSYS fluent.

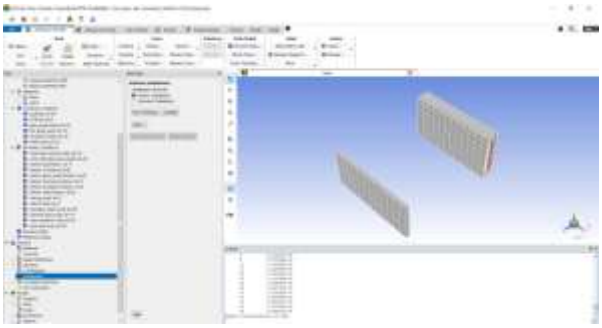


MESHING:

In free meshing a relatively fine mesh is generated.



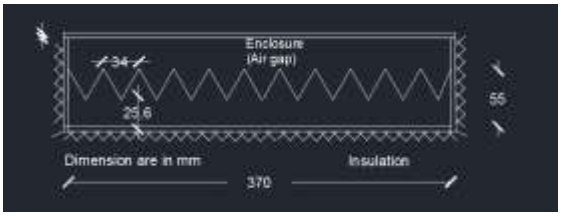
SOLUTION INITIALIZATION: In solution initialization, a hybride initialization is selected and run the solution by 20000 iterations.



DESIGN AND DATA COLLECTION:

The overall dimensions of the test section are 0.9 m in length, 0.4 m in width, and 90 mm in depth, with a back plate made from aluminum sheet of 0.5 mm in thickness and has a 3 mm colorless glass cover .The back plate and sidewalls of the test section are thermally insulated by 50 mm glass fiber (thermal conductivity about 0.038 W/mK) and are contained in an outer hardwood frame. A V-corrugated plate with apex angle of 60^0 placed below the glass cover forms the airflow channel below it with the back plate and the sidewalls, and at the same time an enclosure air gap is formed between its upper surface and the glass cover. The V-corrugated plate (absorber) is an aluminum sheet with net dimensions of 0.88 m in length, 0.37 m in width, and 0.3 mm in thickness. Thus, the net projected area subjected to the radiation heat flux is 0.3256 m^2. The upper surfaces of both the V-corrugated plate and the back plate were coated with a commercial black paint, with an average coating thickness of about 60 um. The top plane of the test section (glass sheet) is uniformly heated by an incident radiation heat flux. The radiation heat source is an assembly of 10 tungsten lamps whose maximum filament temperature is 2850 K at the full load condition. The lamps are fixed to a frame having the same area as that of the test section, and is placed parallel to it at 1 m above the glass cover. Intensities ranges between a minimum and maximum values of 420–1140 W/m^2.

DIAGRAM:



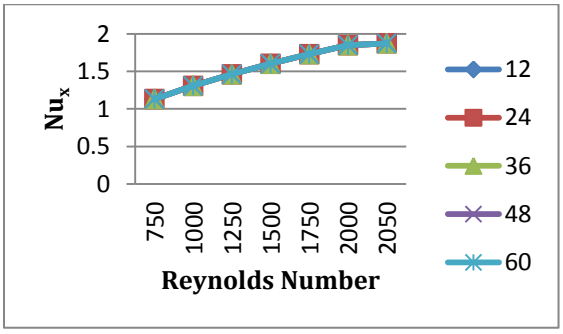
WORKING PRINCIPLE:

The literature survey[1] reveals that work has been carried out to determine the characteristics of forced convection heat transfer for air flowing in channel having a V-Corrugated plate heated by radiation heat flux and thermally insulated side walls. The present work aim to determine the forced convection characteristics of fluid (air) flowing through the channel having V-corrugated upper plate and compare it with channel having plane plate using CFD. The operating parameters studied and their ranges were as follows: air mass flow rate corresponding to Re values ranging from 750 to 2050, incident radiation fluxes were 400, 700, 1000 W/m^2, inlet air bulk temperature ranged from 12 to 60 ^{0}C.

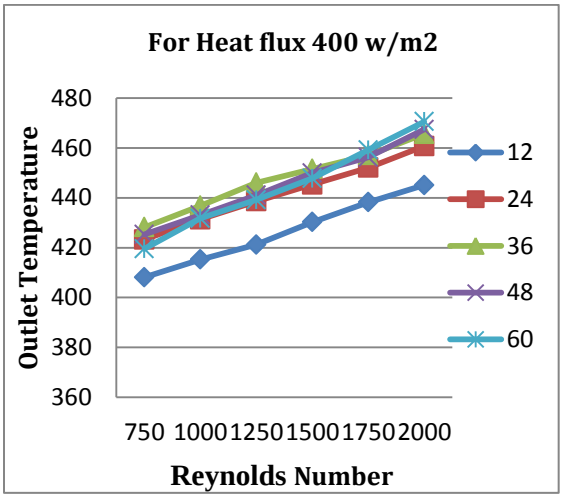
RESULT:

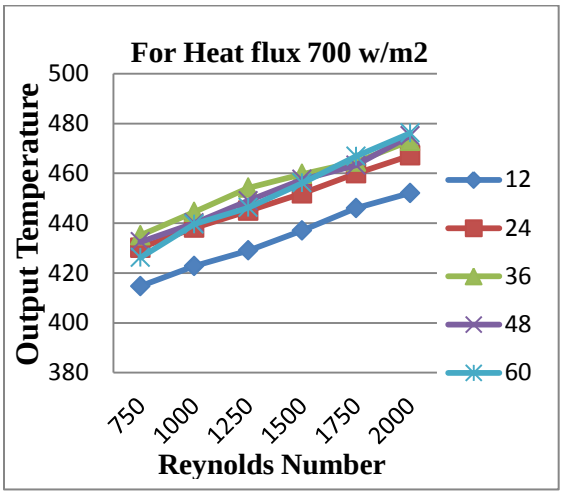
The results of the present work cover the influence of different controlled operating parameters on the convective heat transfer coefficient in terms of local Nusselt number (Nu_x).

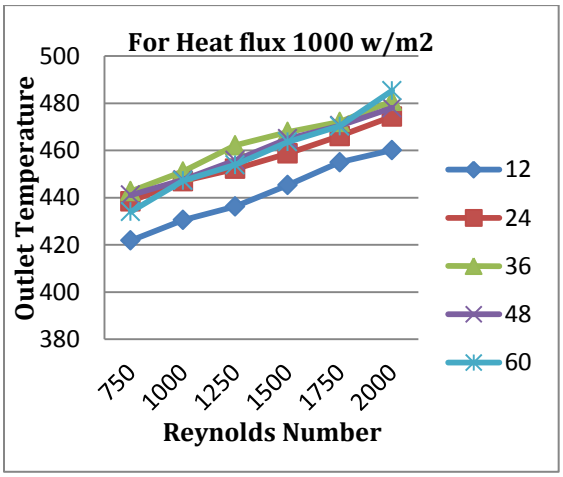
Effect of Reynolds number on local Nusselt number:



Effect of Reynolds number and heat flux on outlet temperature of air:







CONCLUSIONS:

In this research, numerical study on effects of the operating parameters on forced-convection heat transfer for laminar flow of air in a channel having a V-corrugated upper plate heated by radiation heat flux and other walls are thermally insulated has been carried out. The parameters studied and their ranges were the flow Reynolds number (Re) ranging from 750 to 2050, incident radiation heat flux (qinc) values of 400, 700, 1000 W/m^2, inlet air bulk temperature to the channel ($Tb_{,in}$) changed from 12 to 60 ^{0}c. The results show that:

• The effect of the flow Reynolds number values (Re) on the local Nusselt number values (Nux) is clear and more significant at the channel entrance region.

Increasing the incident radiation heat flux values (q_{inc}) leads to an increase in Nux values.

• The results indicate that there are significant increases in Nu_x in the channel entrance region due to the increase in inlet air bulk temperature and this influence diminishes downstream.

REFERENCE:

1]Ahmad Hamza H. Ali, "Study on laminar flow forced convection in a channel with upper V-corrugated plate heated by radiation",Ph.D Thesis, Muroran Institute of Technology, Hokkaido, Japan 1998.