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CFD Analysis of Flow and Heat Transfer in Solar Air Heater Duct by using V-Shaped Inclined Continuous Ribs on Absorber Plate

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***Abstract*— A solar air heater utilizes solar thermal energy to heat the air and further it can be used efficiently in space heating and industrial process heating. An absorber plate of good thermal conductivity is exposed to green renewable solar energy and thus gets heated. The air thus gets heated by the phenomenon of forced convection by the absorber plate. Many attempts were made by the researchers to destroy the laminar sub layer thus formed, by adding artificial roughness to the absorber plate. The roughness obstructs the laminar flow of air near the surface thus create turbulence. The turbulence aid the enhancement of heat transfer between the absorber plate and the air. Here an attempt is made to analyze the heat transfer between smooth absorber plate surface and air flowing in the duct due to forced convection, also when artificially roughened absorber plate surface used instead through computational fluid dynamics simulation by using STAR-CCM+ software. There is appreciable increase in temperature at outlet in solar air heaters using artificially roughened absorber plates. The V-shaped rib roughness gives high rate of heat transfer.**

Keywords—Solar air heater, heat transfer, Reynolds number, CFD, Star-CCM+

I. INTRODUCTION

The thermal efficiency of solar air heaters has been found to be generally poor because of their inherently low heat transfer capability between absorber plate and air flowing in the duct. It has been found that main thermal resistance to the convective heat transfer is due to the formation of convective boundary layer on heat transferring surface. Efforts for increasing heat transfer have been directed towards artificially destroying or disturbing this boundary layer. The use of artificial roughness on a surface is an effective technique to enhance heat transfer to fluid flowing in the duct.

Sanjay Sharma, Ranjit Singh and Brij Bhushan conducted CFD based investigation in order to study heat transfer and friction characteristics of solar air heater duct roughened with formation of square type protrusions. It has been observed that with application of such type of artificial roughness, heat transfer coefficient enhances at the cost of friction penalty. M.K.Mittal and Varun carried out experiments by providing different types of roughness elements on the absorber plate. They concluded that there is a considerable enhancement in the effective efficiency of solar air heaters having rounded duct provided with different types of roughness elements. Solar air heaters having inclined ribs as roughness elements is found to have better efficiency in the higher ranges of Reynolds number. However, expanded metal mesh is found suitable roughness element in lower range of Reynolds number. Varun and R.P. Saini presented a paper on investigation of thermal performance of solar air heater having roughness elements as a combination of inclined and transverse ribs on the absorber plate and conclude that thermal performance of roughened solar air heater is influenced by the roughness parameters and the best performance has been found for roughness parameter that yield maximum heat transfer coefficient. Results have been compared with those of a smooth duct under similar flow conditions to determine heat transfer coefficient and friction factor.

II EXPERIMENTAL SET-UP

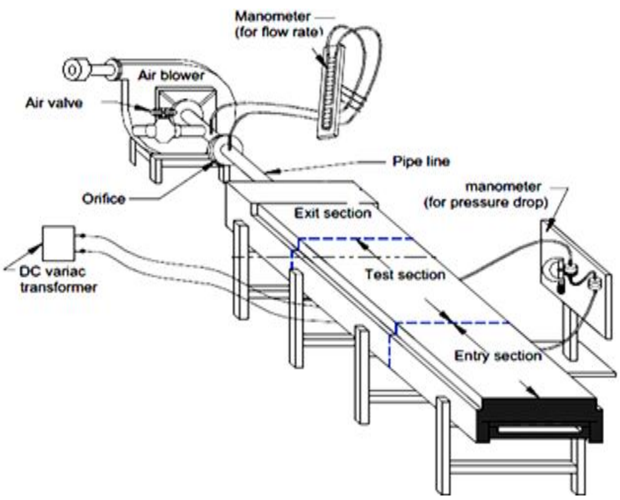

Fig. 1. Schematic of Solar air heater

A schematic diagram of experimental set-up is shown in fig 1. A rectangular wooden duct with interior dimensions of $2400x150x15mm^3$ is virtually divided into three sections. They are entry section, test section and exit section of length 800, 1000 and 600mm respectively was fabricated accordance with recommendation of ASHRAE standard.

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III SEQUENCE OF OPERATIONS IN STAR-CCM+

A workflow is the sequence of operations you must work through in order to achieve a certain result.
Prepare the Geometry→ Construct the Simulation Topology→Create the Mesh→Define the physics→Prepare the Analysis→Run the Simulation→Analyze the Results.

IV ROUGH PLATE

A. *ADDING V-RIBS AS ARTIFICIAL ROUGHNESS ON ABSORBER PLATE PRE-PROCESSING*

Creating a 3D-CAD Model

- To create a new 3D-CAD model right-click on the Geometry 3D-CAD models node and select New as discussed in smooth plate.
- This action creates a new 3D-CAD model node under the Geometry 3D-CAD model 1 node and activates 3D-CAD.

Creating a rectangle and extruding

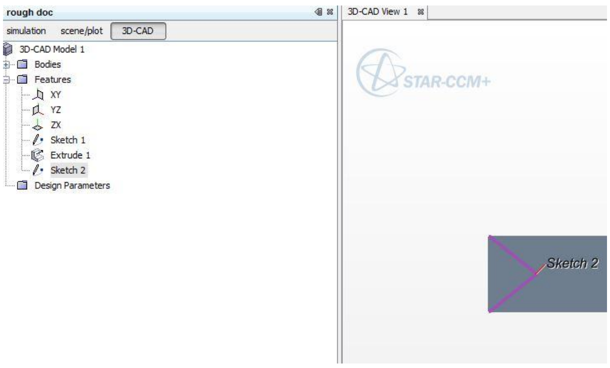
- Click on the (Create rectangle) button in the *Create Sketch Entities* Panel.
- Draw the rectangle of dimensions 150mm*15mm.
- Right click on the sketch1 node in 3D CAD panel select create extrude. In the dialog box give the extrusion dimension as 1.0 m and click OK.
- A box of 1m length apperas on graphics window.
- Save the 3D CAD model.

PARTS

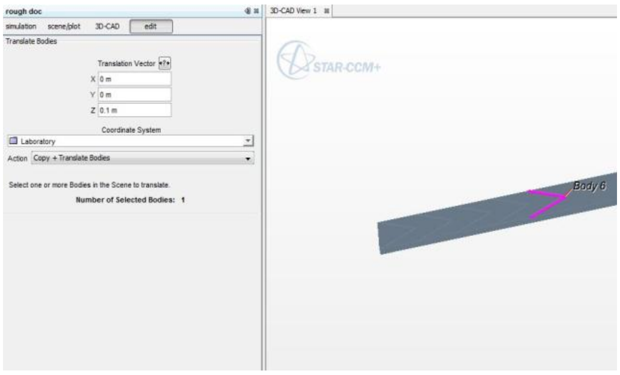
- Move to the tab of simulation
- In the simulation tree, right click on Body 1 node in geometry node.
- Select new geometry part option and click OK in dialog box with default settings.

Creating ribs on the Aluminum plate surface

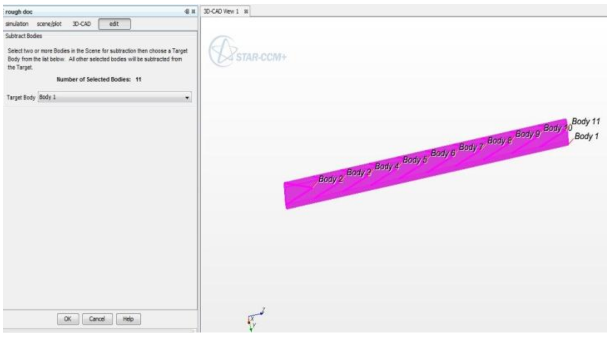
- Go to the 3D-CAD tab to edit the sketch.
- Now select the required co-ordinate system as ZX plane.
- Right click on ZX create sketch select the line icon in the tab draw a triangle with end points as (0,0),(0.095,0.075) and (0,0.15).
- Similarly draw an outer triangle at a distance 0.005m with co-ordinates as (0.005,0),(0.005,0.075) and (0.005,0.15).

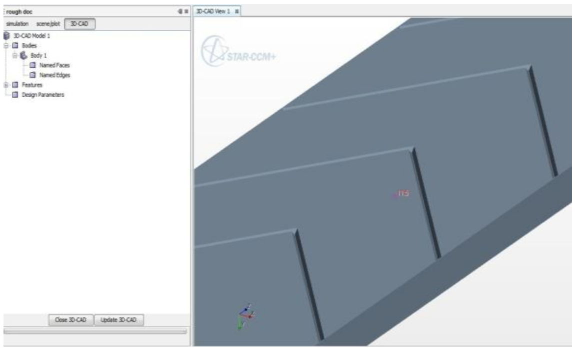


- Right click on the sketch2 node and select create extrude option select extrude as inward set the draft angle as required body interaction as none and
- Click OK.
- Now two bodies are created. Right click on body2 node Transform Translate set Z co-ordinate as 0.1m select Copy+Translate option in the same dialog box and click OK.



- In the same way 10 bodies are created. Select the 10 bodies right click and select **Boolean Subtract** select the target body as body1 OK.





- Now the 11 bodies are converted as a single body.

V RESULTS

TABLE.1 TEMPERATURE ANALYSIS

Position along duct length	Smooth plate temperatures	Rough plate temperatures
0	303	303
0.2	304.831	305.869
0.4	306.516	307.68
0.6	308.062	309.298
0.8	309.421	310.766
1	310.813	311.97

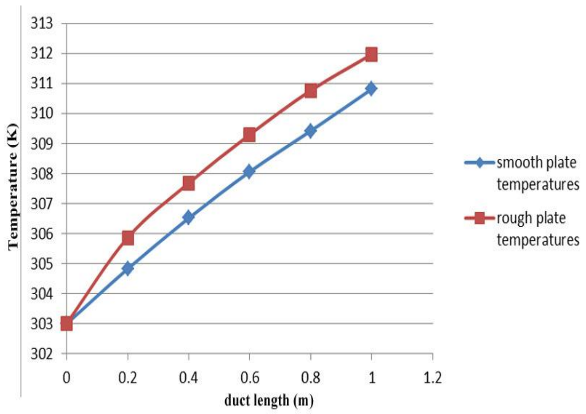


Figure. 2. Temperature v_s Duct length

Figure.2 gives the data about variation of temperature Vs duct length for smooth and rough plates. It is observed that the temperature variation is higher from inlet to outlet in case of rough plate configurations. This is because of the adding V-ribs to the heat transfer plate by which the convective heat transfer has been enhanced.

TABLE.2 VELOCITY ANALYSIS

Position along duct length	Smooth plate velocity	Rough plate velocity
0	4.696	4.696
0.2	4.707	4.733
0.4	4.731	4.7568
0.6	4.7457	4.78067
0.8	4.778	4.8152
1	4.741	4.8

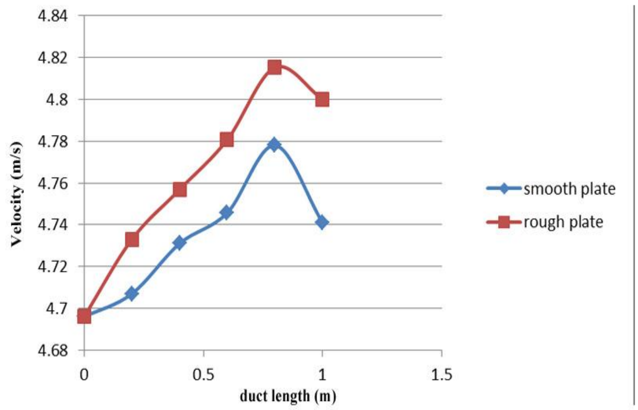


Figure.3. Velocity vs. Duct length

Figure. 3 give the graphical representation of data about the variation of Velocity Vs. Duct length for smooth and rough plates. It is observed that in the case of rough plate velocities are increased from the inlet to outlet of the duct. This is because the temperatures in the case of rough plate are higher. So, the density of air is going to reduce higher in case of rough plate. At the same time the mass flow rate of air is same in both the cases. So, it is justified. At the exit the velocities are showing decreasing mode in both the cases. This is due to; the outlet is connected to the open room. Hence the velocities once again come to the outlet condition.

TABLE.3 PRESSURE ANALYSIS

Position along duct length	Smooth plate Pressure	Rough plate Pressure
0	28.212	28.212
0.2	24.63	23.83
0.4	20.957	19.17
0.6	17.293	14.56
0.8	13.637	9.866
1	10.237	5.261

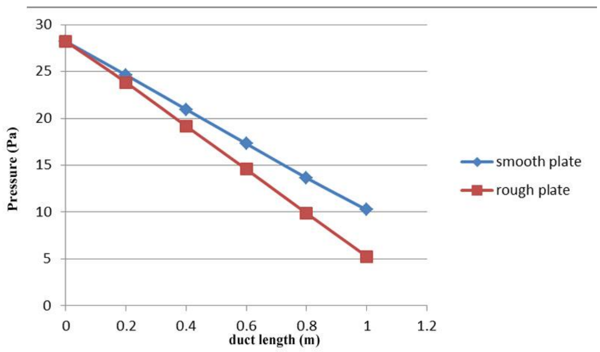


Figure. 4. Pressure vs. Duct length

Figure.4 gives the graphical representation of data about the variation of Pressure Vs Duct length for smooth and rough plates. It is clear that the pressure losses in case of rough plate are due to the obstacle. But the variation is small. It is also noticed that the pressure drop towards the outlet is more in both the cases and follows a similar trend.

TABLE.4 TURBULENT KINETIC ENERGY ANALYSIS

Position along duct length	Smooth plate turbulence kinetic energy	Rough plate turbulence kinetic energy
0	0.0141	0.008803
0.2	0.261	0.2458
0.4	0.2666	0.2501
0.6	0.2642	0.2516
0.8	0.2661	0.2526
1	0.2789	0.2434

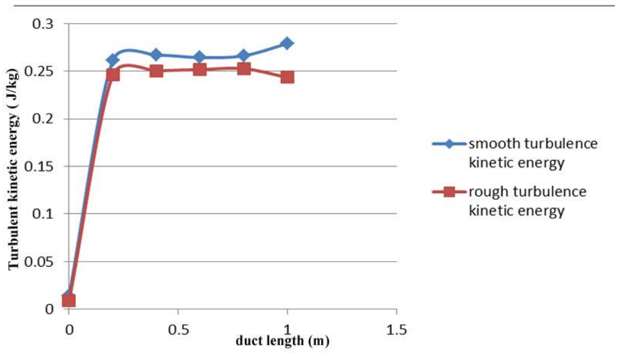


Figure. 5 Turbulence Kinetic Energy vs. Duct length

Figure. 5 Turbulence Kinetic Energy can be produced by fluid shear, friction or buoyancy or through external forcing at low frequency eddy scales. Turbulence Kinetic Energy is then transferred to the turbulence energy and is dissipated by viscous forces at the Kolmogorov scale. This is the process of production, transport and dissipation. It is clear that in TKE Vs Duct length, the dissipation rate is higher in case of rough plate. This indicates that the fluctuating motion due to roughness towards the outlet is more.

CONCLUSIONS

- An attempt has been made to carryout CFD based analysis to fluid flow and heat transfer characteristics of a solar air heater having roughened duct provided with artificial roughness in V-shaped geometry.
- Combined effect of swirling motion, detachment and reattachment of fluid which was considered to be responsible in the increase of heat transfer rate has been observed during CFD analysis.
- There is appreciable increase in temperature at outlet in solar air heaters using artificially roughened absorber plates.
- Compared to smooth absorber plate, there is no much pressure drop arcoss the duct even in case of rough absorber plate.
- The V-shaped rib roughness gives high rate of heat transfer thus this type of surface roughness plate can be recommended to be used in solar air heat

REFERENCES

[1] Ashish kumar sharma, Thakur NS. “CFD based fluid flow in heat transfer analysis of a v-shaped roughened surface solar air heater”. Intenational journal of engineering science and technology (IJEST) vol-4 No.5 may 2012.
[2] Brij Bhushan, Ranjit Singh. “Nusselt number and friction factor coreltions for solar air heater duct having artificially roughened absorber plate”. Solar energy 85[2011] 1109-1118.
[3] Lanjewar A, Bhagoria JL, Sarviya RM. Experimental study of augmented heat transfer and friction in solar air heater with different orientations of W-rib roughness. Experimental thermal and fluid science 35[2011] 986-995.
[4] Gupta MK, Kaushik SC. Performance evaluation of solar air heater having expanded metal mesh and arrtificial roughness on absorber plate. International journal of thermal sciences 48[2009]1007-1016.
[5] Saini SK, Saini RP. Development of corelations for nusselt number and friction factor for solar air heater with roughened duct having arc shaped wire as artificial roughness. Solar energy 82[2008] 1118-1130.
[6] Varun, Saini RP, Singal SK. Investigation of thermal performance of solar air heater having roughness elements as a combination of inclined and transverse ribs on the absorber plate. Renewable energy 33[2008] 1398-1405.
[7] Aharwal KR, Gandhi DK, Saini JS. Experimental investigation on heat transfer enhancement due to a gap in an inclined continuous rib arrangement in a rectangular duct of solar air heater. Renewable energy 33[2008]585-596.
[8] Mittal MK, Varun, Saini RP, Singal SK. Effective efficiency of solar air heater having different types of roughness elements on the absorber plate. Energy 32[2007] 739-745.
[9] Brij Bhusan, Ranjit Singh, A review on methodology of artificial roughness used in duct of solar air heater. Energy 35[2010] 202-212.
[10] Vishavjeet Singh HANS, Saini RP, Saini JS. Performance of artificially roughened solar air heater- A Review Renewable and sustainable energy reviews 13 2009 1854-1869.