Performance Analysis Of Double Inclination Ribbed Solar Air Heater Rectangular Duct By Liquid Crystal Thermography

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Abstract : The actual aim of this study is to enhancement of the transfer of heat from a double inclined artificially roughened ribbed rectangular duct, by using Liquid Crystal thermography technique. This artificially roughened rectangular duct has aspect ratio of 5.0. The investigation has relative roughness height (e/Dh) of 0.034, angle of attack of fluid flow (α) of 60^0 for a fixed relative pitch of 10 and Reynolds number (Re) range of 4000–12000. In this study Liquid Cristal Thermography (LCT) is used to determine the heat transfer distribution on the ribbed surface. Results has been compared with those of the smooth duct on similar flow conditions to determine the enhancement in heat transfer coefficient.

Keywords

Solar Air Heater, Heat Transfer, Artificial Roughness, Liquid Cristal Thermography

1. Introduction

The energy demand is rise incessantly and speedily, and it's not possible to satisfy the long run demand with the current on the market exhaustible energy sources. So, the technology is that specialize in harnessing new and renewable sources of energy. Further, the traditional energy sources area unit inflicting associate threat risk to the earth life. The utilization of alternative energy is intelligent possibility for the utilization of human beings that is available freed from value, in abundant and may be a clean supply for numerous applications.

In this study heat transfer coefficient of rib roughened square channel is measured by using liquid crystal thermography technique. LCT is a optical thermal visualization technique in which thermo chromic liquid crystal (TLC) response to temperature.

Thermo chromic liquid crystals (TLC) are materials that change their reflected colour as a function of temperature when illuminated by white light. More artificial roughened element geometries over the duct has been investigated by many authors in the last few years. Sandeep Jaiswal, K. R. Aharwal (2015) done his investigation on Transient Analysis of Transverse Ribbed Rectangular Duct by Liquid Crystal Thermography and it has been observed that the enhancement of heat transfer for proposed rib roughness arrangement. Momin, J.S. Saini, S.C. Solanki (2002) shows in his work, results of an experimental study of the effect of geometrical parameters of V-shaped rib elements on transfer of heat and fluid flow characteristics of an artificial roughned rectangular duct of solar air heater with absorber plate having V-shaped ribs on its underside has been reported. Sahu and Bhagoria (2005) was done performance analysis of solar air heater duct having straight discrete ribs P/e= 6.67-20, e/D= 0.0338, AR= 8, α= 90^0, Re= 3000-12000 with this value of parameters maximum value of Nusselt number was reported.

2. The Experiment

a. Apparatus

In this apparatus the main components are heater, rectangular test section, orifice meter, U tube manometer, illuminating light system, camera, data logger, computer, centrifugal blower and motor.

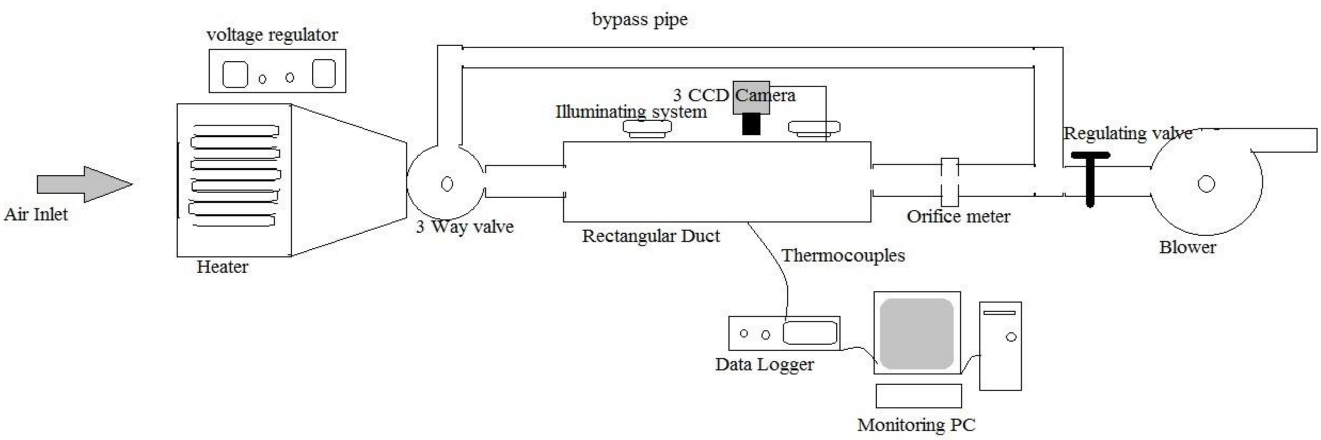


Fig.1 Schematic Diagram of Experimental setup

The test section is a rectangular channel with AR= 5.0, width= 200mm, height= 40mm and a length= 1500mm, constructed with 12mm thick Cast Acrylic sheet. Heater is used to heat up the incoming air. Toshiba's 3CCD camera is used to capture the thermal images. 20w LED light source is used as a illuminating system.

b. Roughness Geometry

Roughness geometry parameters are Range of Reynolds number (Re) is 4000 -12000, Relative roughness pitch (P/e) =10, Angle of attack (α) =60°, Diameter of rib (e) is 1mm, Width of plate (w) is 200mm, Length of plate (L) is 1500mm and Relative roughness height (e/D) has been chosen 0.034.

Fig. 2 Actual image of 60° double inclined ribs geometry

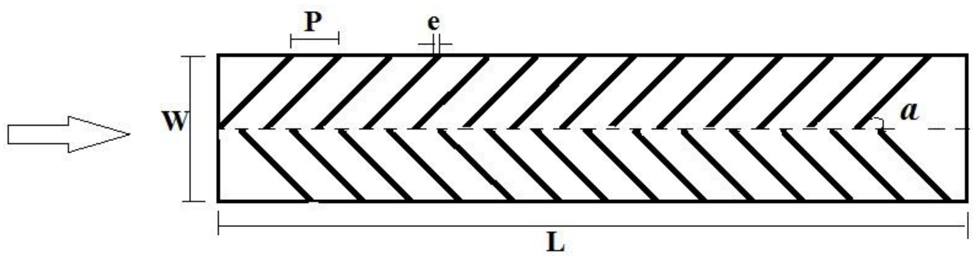


Fig. 3 Schematic diagram of double inclined (60 degree) rib geometry

c. Experimental Procedure

Liquid Cristal Thermography technique is used to measure temp. distribution in the duration of heat transfer from hot air to the test surface. Apply the thermo chromic liquid crystal sheet on to the surface of the test section in the duct. Liquid crystal sheets used in this experiment is in the temperature range of 55˚C to 60˚C. The test section initially must be kept at constant temperature level and after that quickly exposed to a high temperature flow. Maintain the temperature with in the range of liquid crystal sheet. When air is maintain with in the range of LC sheet, then air is allow to pass through the main test section and during this bypass line is closed by operating three way valve. Measure and record the temperature response of LC sheet. Temperature response of LC sheet is captured by 3CCD Camera with suitable illuminating light source system and the temperature is recorded by data logger. After recording temperature and colour image of the LC sheet in different points of test section, we made a relationship between colour and temperature. Now the colour response of the LC sheet and their variation with temperature can be used to get exact temperature of any point of the test section.

d. Data Reduction

The convective heat transfer coefficient is determined by using following relationship**.**

Heat Transfer Coefficient : $h = Q_a / A_p (T_{pav}\text{-}T_{fav})$

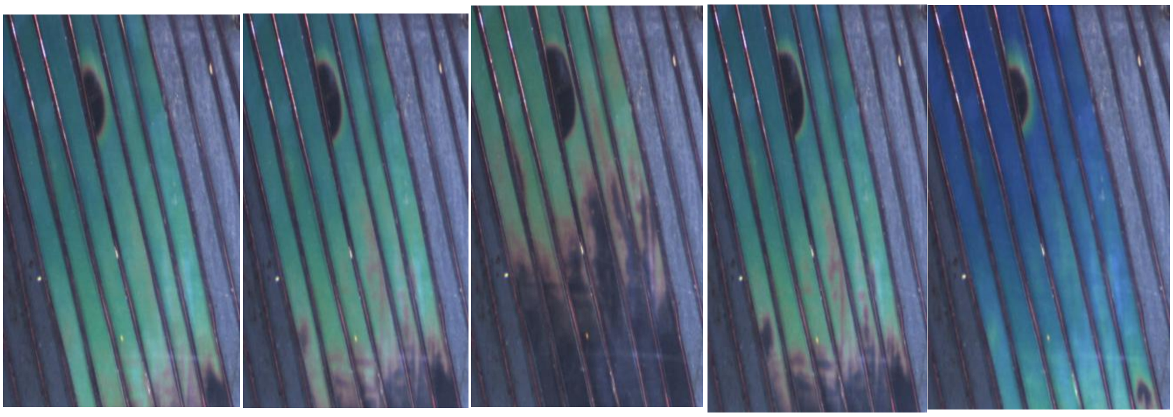
Nusselt Number : $N_u = h \times D_h / k$

Reynolds Number : $R_e = V D_h / \upsilon$

where, Q_a is a heat gained by air, A_p is a surface area of the rectangular plate, υ is a kinematic viscosity of air at T_{fav}, D_h is a hydraulic diameter of duct, k is a thermal conductivity of air.

3. Results and Discussion

Calibration of liquid crystal sheet of specific band width of temperature range 55^0 C to 60^0 C is performed and after that calibration comparison of colour images hue value with that graph we can calculate exact temperature on the test surface.



$\mathring{m}_1$ $\mathring{m}_2$ $\mathring{m}_3$ $\mathring{m}_4$ $\mathring{m}_5$

Fig.4 Actual thermal images of ribs in different mass flow rate

S. No.	$\mathring{m}$ (kg/s)	V (m/s)	Re	Nu
1.	0.00739	1.27	3490	5.91
2.	0.01044	1.80	4928	7.94
3.	0.01279	2.21	6032	9.74
4.	0.01476	2.55	6956	10.54
5.	0.01648	2.86	7749	12.31

Table.1 Results for 60° inclined ribs

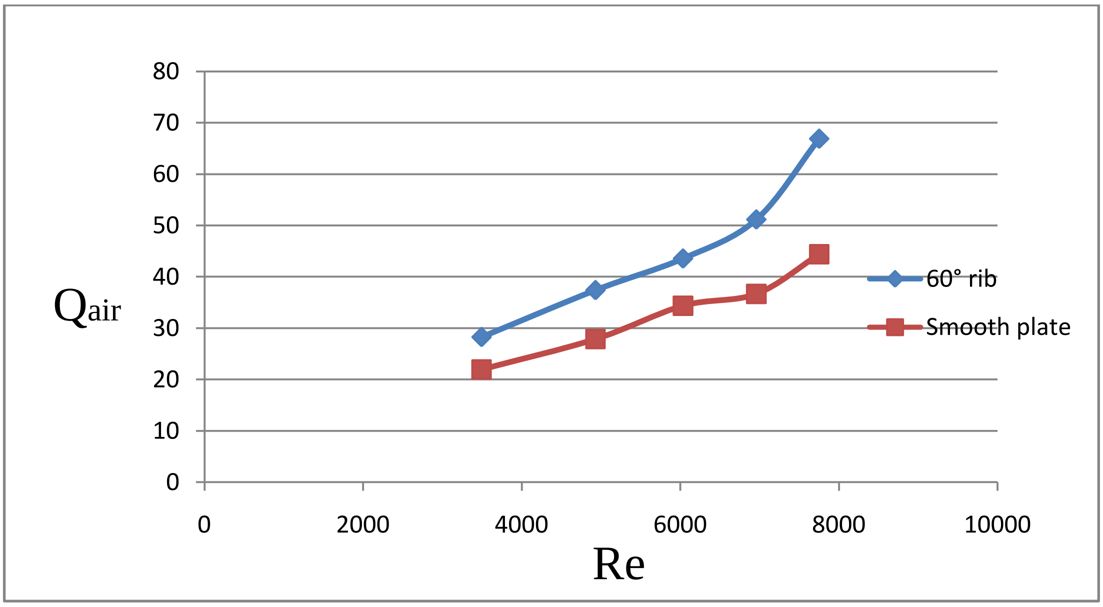


Fig. 5 comparison between Qair and Re for 60° ribs and smooth plate

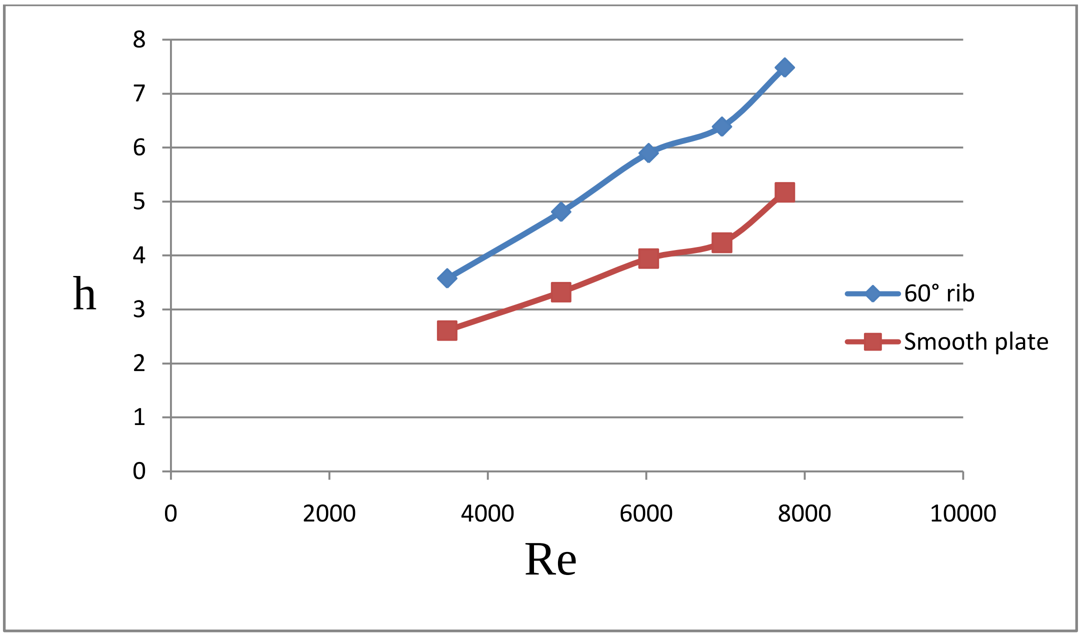


Fig. 6 comparison between h and Re for 60° ribs and smooth plate

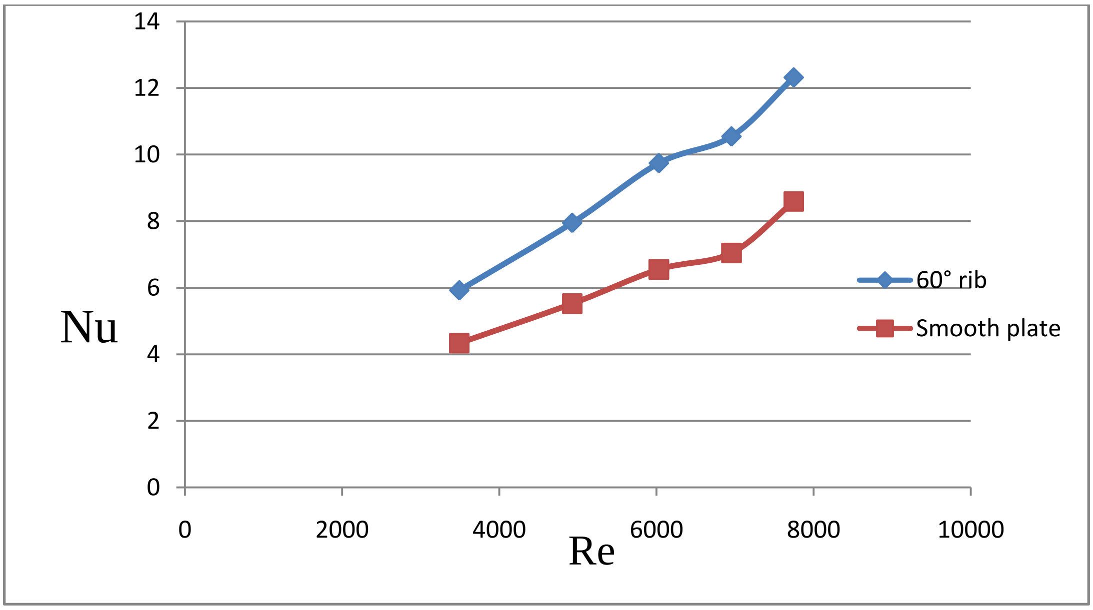


Fig. 7 comparison between Nu and Re for 60° ribs and smooth plate

4. Conclusions

Experimental test is performed with the liquid crystal thermography technique for the selected design parameters of artificial rib geometry to find the local Nusselt number and this results of artificial roughened duct has been compared with the smooth duct on similar flow condition to determine heat transfer. It is observed that the enhancement of heat transfer for proposed rib geometry is better than the smooth duct.

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