ISSN 2395-1621

Forced convection heat transfer augmentation from ribbed surface

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ABSTRACT

Heat transfer Enhancement techniques are used in heat exchanger systems in order to enhance heat transfer & improve thermal performance. one of the ways to enhance heat transfer rate is to increase the effective surface area & residence time of the heat transfer fluid. The thermal characteristics of turbulent flows over ribbed surfaces are of great importance for engineering applications due to the heat transfer enhancement. In experimental study To avoid high pressure drop and pumping power for the fluid, low velocity flow is often applied. Ribs can be used to induce turbulence and thus enhance the heat transfer. The velocity and temperature measurements carried out in a wind tunnel were recorded by a constant- temperature hot wire anemometer and a copper-constant thermocouple, respectively. The ribbed wall destabilized the flow. The separations and reattachments over the ribbed wall increase fluid mixing, create flow unsteadiness, interrupt the development of the thermal boundary layer and enhance the heat transfer. The flow rates have been varied between the Reynolds numbers 500 and 10.000, covering the range from laminar to low turbulent flow.

The results show that Ribbed Wall Effectively Enhances The Heat Transfer performance. One can easily detect the areas with good heat transfer (dense fringe pattern at the upstream sides of the ribs) and the ones with bad heat transfer (downstream sides, recirculation zones) and the flow reattachment

ARTICLE INFO

Article History :

Received:2nd November 2015

Received in revised form:

4th November 2015

Accepted : 5th November 2015

Keywords: **heat transfer enhancement, ribbed surfaces forced convection etc**

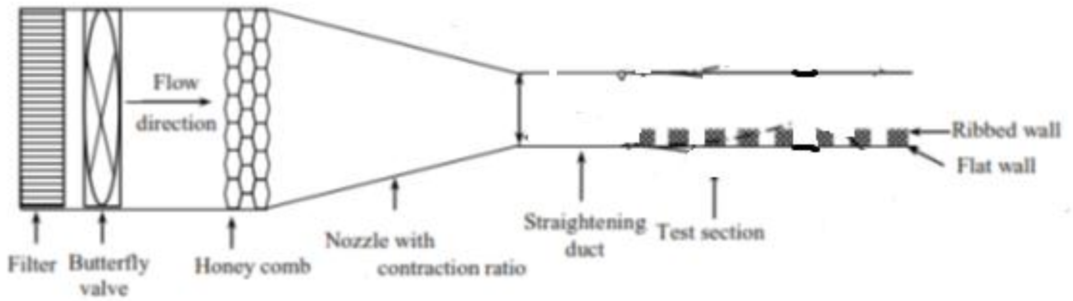
I. INTRODUCTION

Enhancement of forced convection is important in several engineering applications.Surface modifications like rib-roughening are commonly used in applications such as compact heat exchangers and internal cooling of gas turbine blades and vanes. This paper gives a brief summary of convective heat transfer and fluid flow in some ribbed ducts. Details of the flow pattern and the influence of rib configuration and arrangement on the heattransfer are presented. Experimental and numerical investigations of the forced convection heat transfer in flat channels with rectangular cross section are presented in this report. The heat transfer is enhanced by rib-roughened surfaces applied to the wider walls of the duct. The flow rates have been varied between the Reynolds numbers 500 and 10.000, covering the range from laminar to low turbulent flow. The efficiency of compact heat exchangers can be improved for example by means of

The efficiency of compact heat exchangers can be improved for example by means of boundary layer modification and active surface enlargement ribs are often used in design of heat exchanger ducts in order to enhance the heat transfer rate and thus to improve the overall process efficiency. Historically ribs have been introduced in the cooling passages of gas turbine blades because of the extremely high thermal loads and reduced dimensions. It has been found that the main thermal resistance to the convective heat transfer is due to the presence of a viscous sub-layer on the heat-transferring surfaces. The presence of ribs makes the viscous sub-layer break down by virtue of flow separation and reattachment, which reduces the thermal resistance and considerably enhances the heat transfer. However, the use of ribs gives rise to higher friction and hence higher pumping power. Thus, many experimental studies have been carried out to determine the rib configuration and arrangement that produce optimum effects. Attempts have been made to overcome the adverse effect by changing the geometry of the rib cross section. In addition to varying the rib cross section profile, another way to avoid hot spots is to replace the solid-typeribs by perforated ribs. Because part of the air flow passes through the perforated ribs and directly impinges on therecirculating region behind the rib, the hot spots may not arise.Heat transfer enhancement by means of various techniques is an important task for research, which is also paid tribute to by the huge and growing number of publications on this subject, especially in recent times.

II.EXPERIMENTAL TEST SET-UP

The presence of the ribs significantly changes the thermal characteristics of the flows due to the velocity field varies. The ribbed wall destabilized the flow. The separations and reattachments over the ribbed wall increase fluid mixing, create flow unsteadiness, interrupt the development of the thermal boundary layer and enhance the heat transfer. In order to understand the heat transfer evolution of this complex flows, experiments were carried out in turbulent flows.The experimental investigation carried out in a blowing type, low-speed wind-tunnel, as shown in Fig



the thermocouples were embedded at interval of 15 mm in the stream wise direction on the ribbed wall.The boundary layers identified by shape factor (*H*=□*/□), intermittency factor *(□=(H-HL)/(HT-HL))*, momentum thickness Reynolds numbers (*Re□=U□/v*) and stream wise distance Reynolds numbers (*Rex=Ux/v*) in the primarily flat plate measurements, where □*, □, *U*, *v* and *x* is displacement and momentum thickness, mean free stream velocity, kinematic viscosity and stream wise distance respectively, and subscripts L and T refer to laminar and turbulent flows. The heat transfer coefficient and experimental Nusselt number were calculated by *h=q/(Tw-T0)* and *Nu=hx/k* respectively, where *q=qf-qo*, *qf*and *qo*indicate to flow-on and flow-off powers and *Tw*, *T0* and *k* refer to wall temperature, free stream temperature and thermal conductivity, respectively.

Fig. Actual Experimental Set-Up

Following are the components of experimental setup with Blower and
1) Acrylic duct, 2) specimen rod 3) Temperature Indicator
4) Plate Heater 5) Voltmeter and Ammeter 6) Dimmer-stat
The duct is used to isolate the air given out by the blower.
2)Specimens/Rod
It is the main component of the experiment. The heat transfer rate is to be measured from the ribbed wall.Fins having height 0.015m and
thickness 0.03m and 8 in number.
3)Temperature Indicator
It consists of thermocouple of 9 in number which is mounted over the specimen at a equal distance 7 on specimen and two thermocouples mounted for inlet and outlet temperature of duct which measures bulk mean temperature.

III.EXPERIMENTAL PROCEDURE

1.The experimental set up is assembled and all the electrical connections.
2. After checking all electrical connections power supply is switched on.
3. The controller on the dimmer-stat is operated to increase the voltage supplied to the rod heater from
zero to a certain value so that the power input to the rod heater is set at 180v.
4. The temperature of the rod is continuously monitored until the plate reaches steady state.
5. After that turn on the blower and measure the flow velocity of air.
6. With the help of flow control valve, control the discharge of air from the blower after the steady stateis reached, temperatures of different thermocouples are recorded from the temperature indicator display and power rating from wattmeter is recorded.

IV.RESULTS AND DISCUSSION

The flow measurements were carried out at the beginning of the flat plate to identify the inlet boundary layer. The shape factor, intermittency factor and momentum thickness Reynolds numbers changed from 1.32, 0.91 and 1900 to 1.30, 0.94 and 2100 respectively with increasing Reynolds number. It can be said from these results, the flow showed turbulent character at the both Reynolds number

The bigger Reynolds number caused 25% higher average heat transfer coefficient over the ribbed wall.This increment can be explained by the augmentation in the turbulent level in the thermal boundary layer and the vortex with greater energy. Due to the strong accelerating and impact effects at the front and rear corners of each rib, the heat transfer coefficients appeared as large and small peaks there respectively.Besides, the presence of the separating bubbles between ribs caused small heat transfer coefficients which had no apparent contribution to the heat transfer from the ribs.

I. CONCLUSIONS

An experimental study was performed to understand the behavior of the heat transfer characteristics over the ribbed walls in turbulent boundary layer under the effect of Reynolds number. The findings of the present works can be summarized as follows:
The presence of the ribs increased the turbulent heat transfer comparing to the flat plate. The heat transfer enhancement ratios of the ribbed wall were bigger. The maximum Nusselt number values of the ribbed wall were obtained at the beginning corner of the first rib, while the minimum values were determined between the last two ribs. The heat transfer coefficients increased with Reynolds number for all the walls and the wall shape (ribbed) was more effective parameter than the Reynolds Number on the heat transfer.

Turbulence promoters (ribs) applied to the heat transferring surfaces of heat exchanger ducts can induce turbulence, and will cause a transition from laminar to turbulent flow at lower Reynolds numbers compared to a smooth duct.

These ribs show their best effect in regions where they can induce turbulence, i.e., for Reynolds numbers that are a little bit smaller than the critical Reynolds number. The most effective rib spacing is at a rib-pitch-to-height ratio of p/e = 10. In general the turbulence promotors show their best effect in the transition region from laminar to turbulent flow. Keeping in mind that the enhancement of heat transfer has to be paid by a higher pressure drop the application of grooves in the spacing of the ribs was invesitigated and showed an improvement, especially by an earlier laminar-turbulent transition.

II. FUTURE SCOPE

In this paper the heat transfer characteristics of the ribbed surface are obtained in the turbulent flow. In the forthcoming work, the heat transfer and flow characteristics of the flow surfaces will be investigated together to better understand the complex flow structure. The experiments will be carried out both in laminar and turbulent flows and supported with the numerical analyses.

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