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Enhancement of heat transfer by changing angle of the rib in triangular duct using experimental analysis

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Abstract

Rough surfaces are one of the most effective techniques to increase heat transfer. In this study, we have created rough surfaces in plain duct by (e/Dh = 0.043) with changing angle of rib 45^0 and 60^0. So we have developed an experimental setup with dimensions of the triangular duct base and height is 200mm and 350mm respectively. We had taken different readings at a constant flow rate and changing the temperature of the surface plate. From experimentation, we have found Reynolds number, Nusselt number and friction factor for three plates (plain, 45^0 and 60^0) and found 45^0 angle rib to have better results. Artificial roughness creates the turbulence to the flow which leads to increase the heat transfer between the air and the heated wall. Roughness is created in such a way that it breaks the laminar sub layer region i.e. near the wall. There are various method to provide artificial roughness on the absorber plate such as casting, forming, machining, blasting, welding ribs and/or fixing thin circular wires, etc. The easiest and cheapest way of providing artificial roughness on the underside of the absorber plate is sticking of ribs The scope for this study would focus all necessary activities for benchmarking the existing application with the current performance level and performance standards to be set for arriving at the objectives of the dissertation work.

Keywords: *Surfaces (plain, 45^0 and 60^0), Reynolds number, Nusselt number and friction factor.*

1.Introduction

The subject of fluid flow and heat transfer in noncircular ducts from a fundamental viewpoint has been virtually neglected in the literature. In industrial practice generally using round pipes in heat transfer equipment. Unconventional heat transfer design problem and the increasing industrial use of noncircular ducts in heat exchangers, the problem becomes more than just academic question. Mixed convection heat transfer in channels characterized by non- circular cross sections is a fundamental issue in many fields such as research and industry fields. Because of its uses in many thermal applications such as compact heat exchangers and solar collectors also cooling of electrical and electronically devices. Different shapes of the cross section area have been analyzed, like square, elliptical, rectangular and triangular, sinusoidal, rhombic etc, even with abbreviated corners.

Artificial roughness provides the turbulence to the flow which leads to increase the heat transfer between the air and the heated wall. Roughness is intervened in such a way that it breaks the laminar sub layer region i.e. near the wall. There are several method to provide artificial roughness on the absorber plate such as casting, forming, machining, and blasting welding ribs and/or fixing thin circular wires, etc. The easiest and cheapest way of providing artificial roughness on the underside of the absorber plate is sticking of ribs.

Turbulent heat transfer in separated flow fields is an attractive and important phenomenon. The detachment stream generated by sudden expansion or contraction in passage, flow over forward and backward facing step, in channel ribs, and used swirl generators in passage, happens in wide range of practical flow geometries such as heat exchangers, atomic reactors, combustors and cooling channels and so on. Separation occurs in turbulent and laminar flows. In the present paper, the turbulent flow separation has been studied to a greater extent. This is because:

a) Turbulent flows are more frequently encountered than laminar flows.

b) Separation is more likely to occur when the flow is turbulent.

c) Due to inertial effects, separation has a much greater influence in turbulent flows.

There is a great change of the local heat transfer rate in the separated flow regions and considerable heat transfer augmentation may result up to the reattachment region. Knowledge of convective heat transfer rate in separation flow regions has been consolidated in this review paper and provided more information and precise analysis associated with heat transfer as well as a complete physical understanding of the flow. For turbulent heat transfer in separated flow, all analyses are preferred eventually depended on experimental. The published experimental papers related to turbulent heat transfer in separated flow, could be categorized into: Sudden expansion, forward and backward facing step, Blunt body, Ribs channel, and Swirl generators.

2.LITERATURE REVIEW

Mahdi et. al [1]had concluded clearly, permeable media with and without nanofluids have great potential for heat transfer enhancement and highly suited to application in practical heat transfer processes. This offers an open door for specialists to develop highly compact and effective heat transfer equipment. In this article, a comprehensive review of previous efforts is presented for different convective flow regimes and heat transfer through porous media with and without nano fluid. The impacts of a few Parameters in permeable media geometry and nano fluid properties, thermal boundary conditions, and sorts of fluid were investigated.

Bharadwaj et al.[2]the range of relative roughness height (e/Dh) is from 0.021 to 0.043, value of angle of attack (α) and relative roughness pitch (p/e) has been 30° and 8 respectively.

The range of Reynolds number is from 5600 to 28000 and aspect ratio of the duct is 1.15. It has been found that the thermo hydraulic performance of artificially roughened triangular solar air heater duct is always more than that of the smooth absorber plate in the range of Reynolds number investigated.

Salem et.al[3] had investigated thermal creating, mixed convection, in a flat equilateral triangular channel heated consistently. A test work has been directed for horizontal equilateral triangular channel, heated uniformly, to investigate thermally developing mixed convection. The channel was (1.5 m) long and constructed from three plane (100 mm) walls to form the equilateral triangular cross section. These experiments had been conducted for range values of ($115 \le af \le 237(W/\text{m}2)$)) of heat flux and for the range ($0.0005 \le m \le 0.0015(kg/\text{sec.})$) of air mass flow rate. The test apparatus has been manufactured first, then a thermocouples have been stickled in proper positions

Togun et.al.[4] had studied review of experimental studies of turbulent heat transfer in separation flow. Enhancement of turbulent heat transfer rate in separation region with sudden expansion in passage or flow over backward and forward facing steps have been chronologically presented with experimental observations. Augmentation of turbulent heat transfer rate in separation flow by introducing swirl generators in pipes, annular pipes, and with sudden expansion in passage has been highlighted. Different geometries of rib with rectangular and square ducts in turbulent flow in a number of studies have confirmed increase of heat transfer coefficient in separation flow behind ribs.

Mohammed et al.[5] had studied by rectangular wing, pair of delta winglets, and a pair of rectangular winglets had been investigated experimentally for Reynolds numbers ranging from (24500) to (75750). The ratio of the cross- sectional area of the test duct to that of the vortex generator (AD/AVG) was remaining constant during experiments. The variables parameters, vortex generator type, angle of attack, and Reynolds number. The variables parameters, vortex generator type, vortex generator angle of attack, and Reynolds number.

Gupta et al.[6] studied fully developed laminar flow and heat transfer in equilateral triangular cross-sectional ducts following serpentine and trapezoidal path. Friction factors for fully developed flow in an equilateral triangular duct containing built-in vortex generators of delta win.

Tamayol et al.[7]had studied analytical solutions presented for laminar fully-developed flow in micro/minichannels of hyperelliptical and regular polygonal cross-sections. The considered geometries cover a wide range of common simply connected shapes including circle, ellipse, rectangle, rhomboid, star-shape, equilateral triangle, square, pentagon, and hexagon. Therefore, the present approach can be considered as a general solution. Predicted results for the velocity distribution and pressure drop are successfully compared with existing analytical solutions and experimental data collected from various sources for a variety of geometries, including: polygonal, rectangular, circular, elliptical, and rhombic cross-sections.

3.PROBLEMS DEFINATION

After reviewing different papers we have seen that there are many methods to improve heat transfer rate by creating roughness in triangular duct but there is no any work was found to improve heat transfer by changing angle of the rib in triangular duct

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4.Methodology

i. To design and develop test section as per design.
ii. To manufacture test rig as per requirement

5.Design of test section

Design of test section for experimental investigation of heat transfer enhancement of triangular duct for artificial roughness For test section according to ref [3]

Parameter	Dimension in mm
e	10
W	200
H	350
P	80

Area of triangle,
A= 0.5×W×H
=34883.72mm^2

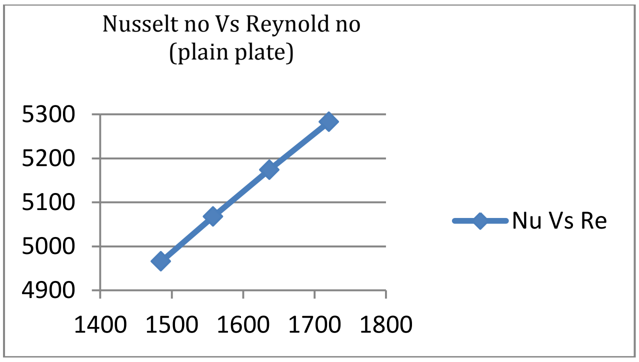
Perimeter of triangle,
P=3×W
=600mm

Hydraulic diameter
D_h= (4×P) ÷A
=232.56mm =0.23m

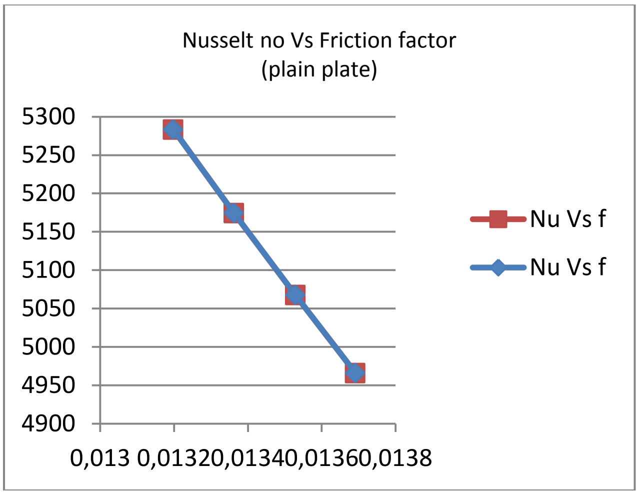
For artificial rough surface:
We have selected angle of attack is= 45^0,60^0.

From above data we have calculated, Value for relative roughness height (e/Dh) is from 0.043 and relative roughness pitch (p/e) has been 8 respectively.
Hence our design is safe for getting more heat transfer rate

6. Results , graphs and discussion

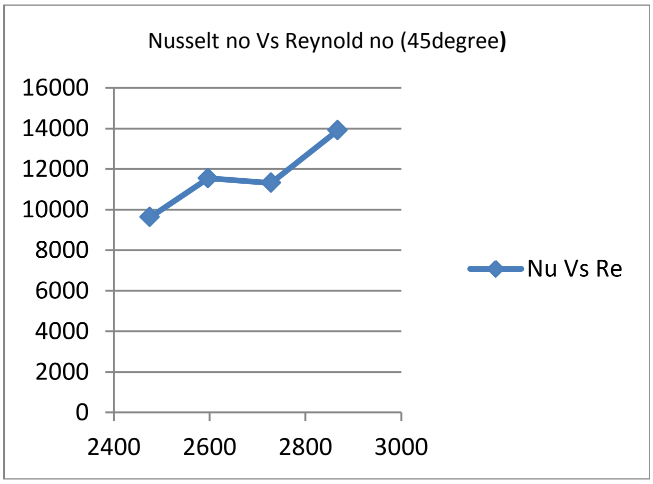


Graph 1: Nusselt no. Vs Reynolds no. for plani duct.

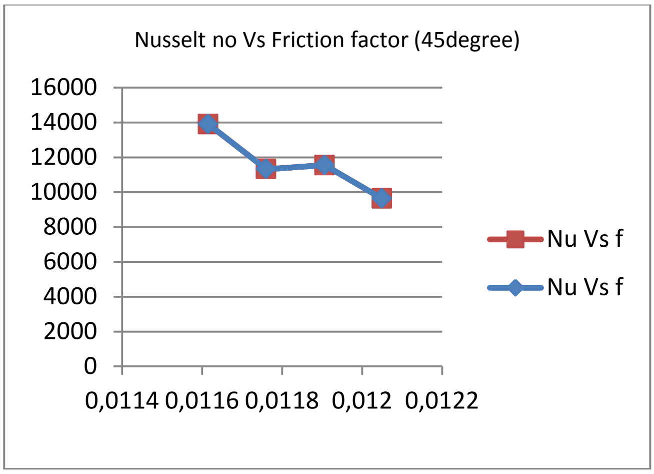


Graph 2: Nusselt no. Vs friction factor for plani duct.

Results graphs and discussion for plain duct
1. From graph 1 it is found that as increasing Nusselt number Reynolds no. increases.
2. From graph 2 it is found that as increasing Nusselt number friction factor decreases.

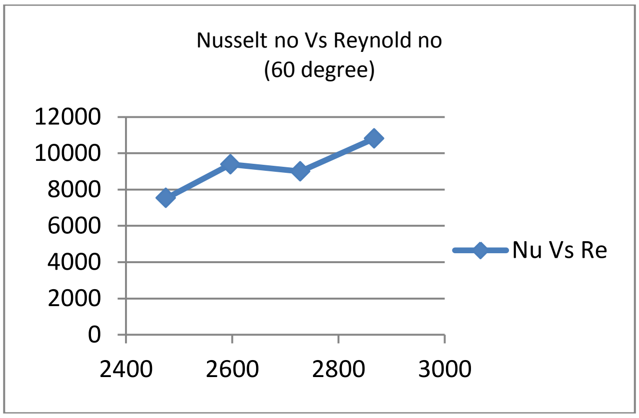


Graph 3: Nusselt no. Vs Reynolds no. for 45^0 rib angle.

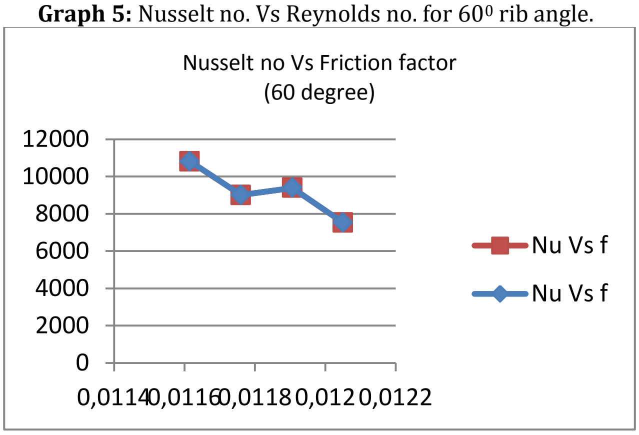


Graph 4: Nusselt no. Vs friction factor for 45^0 rib angle.

Results graphs and discussion for 45^0 rib angle plate.
1. From graph 3 it is found that as increasing Nusselt number Reynolds no. increases. It is found also that for Reynolds number 2596 having higher Nusselt number as compared to Reynolds number 2728.
2. From graph 4 it is found that as increasing Nusselt number friction factor decreases. It is found also that for friction factor 0.01175 having higher Nusselt number as compared to friction factor 0.0119



Graph 5: Nusselt no. Vs Reynolds no. for 60^0 rib angle.



Graph 6: Nusselt no. Vs friction factor for 60^0 rib angle.

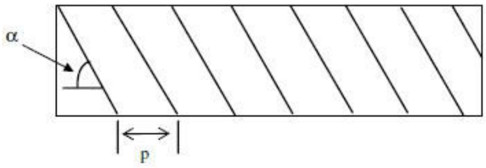
Results graphs and discussion for 60^0 rib angle plate.
1. From graph 5 it is found that as increasing Nusselt number Reynolds no. increases. It is found also that for Reynolds number 2596 having higher Nusselt number as compared to Reynolds number 2728.
2. From graph 6 it is found that as increasing Nusselt number friction factor decreases. It is found also that

for friction factor 0.01175 having higher Nusselt number as compared to friction factor 0.0119

From above experimentation, it is found that for Reynolds number 2596 having higher Nusselt number as compared to Reynolds number 2728 of both angled plates.

7.Experimental Investigation

a. Experimental setup



Sectional view of test section

Photograph of Experimental plate

Specifications:

i) Test section:

Dimensions of triangular duct (W=200mm, H=350, e=10mm, P=80mm).

e/D_h = Relative roughness height =

P/e = Relative roughness pitch= 8.

Value of angle of attack (α) for making roughness is 45^0 And 60^0.

Conclusion

This research work will lead to findings on the effect of artificial rough surface on heat transfer enhancement in triangular duct. It is expected from this research work that the applications of artificial rough surface will enhance the heat transfer in triangular duct by providing turbulence movement of fluid in triangular duct.

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