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EXPERIMENTAL INVESTIGATION OF HEAT TRANSFER AUGMENTATION IN TRIANGULAR DUCT WITH RECTANGULAR WING

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ABSTRACT: This paper includes the study of heat transfer augmentation in triangular duct with rectangular wing with experimentally. The air as working fluid because due to high thermal resistance. The longitudinal vortex generator is the promising technique to enhancement of heat transfer. The longitudinal vortices are produced due to pressure difference generated between front and back surfaces of the vortex generator. An innovative design of triangular shaped duct with rectangular wing vortex generator is mounted on the bottom surface of duct for augmentation of heat transfer rate in plate- fin heat exchanger. The range of Reynolds number is 4*103 to 22*103 taken for development of turbulent zone. As the solution is converged after certain number of iteration, the values of pressure drop, Nusselt number, average temperature and friction factor are calculated for different angle of attack and for different pitch and compared same parameter for plain duct without rectangular wing.

Keywords— Heat Exchanger, Rectangular wing, Reynolds number, Nusselt number, Friction Factor**.**

1. INTRODUCTION

Heat transfer intensify techniques are commonly used in areas such as process industries, heating and cooling in evaporators, thermal power plants, air-conditioning equipment, refrigerators, radiators for space vehicles, automobiles, etc.Heat exchangers are mechanical device which provides the surface area necessary to transfer heat energy from one fluid to another fluid stream .While flowing fluid through the exchanger; the temperature of both fluids may change. The improvement of the performance of heat exchangers with gas as the working fluid becomes particularly important due to the high thermal resistance offered by gases in general. In order to compensate for the poor heat transfer properties of gases, the surface area density of plate heat exchangers can be increased by making use of the secondary fins such as, off - set fins, triangular fins, wavy fins, louvered fins etc. In addition, a promising technique for the enhancement of heat transfer is the use of longitudinal vortex generators.

The longitudinal vortices facilitate the exchange of fluid near the walls with the fluid in the core and hence, the boundary layer is disturbed. It causes the increase in temperature gradient at the surface which leads to the augmentation in heat transfer. An innovative design of triangular shaped secondary fins with rectangular delta wing vortex generator mounted on bottom surface of the channel for enhancing the heat transfer rate in plate-fin heat exchanger. As the solution is converged after certain number of iterations, the values of pressure drop and Nusselt number, Average temperature, friction factor are calculated for different angle of attack and for different locations.

There are varieties of application of heat exchangers like heating and cooling of stream concerned and condensation or evaporation of single or multi component stream concerned. In some other applications the target is to recover and reject heat or sterilize, pasteurize or control a fluid process. Heat augmentation techniques play a vital role for laminar flow, since the heat transfer coefficient is generally low in plain tubes. During recent years, serious attempts have been made to apply different active and passive mechanisms for heat transfer enhancement in compact heat exchangers for the automotive industry, air-conditioning and refrigerant applications, internal cooling for gas turbine blades, electrical circuits in electronic chipsets, etc. Achieving higher heat transfer rates through various augmentation techniques can result in substantial energy savings, more compact and less expensive apparatus with higher thermal efficiency.

The aim of study is to investigate the heat transfer augmentation by rectangular cut winglet in triangular duct. Experiments and numerical investigation are performed to investigate the thermal-fluid characteristics of a flat-fin heat sink with a pair of vortex generators installed in a cross flow channel. It is proposed to estimate the effect of triangular duct with rectangular wing on Nusselt number and friction factor of fluid flow. It is expected that the Nusselt number and friction factor will increase than that of number of wing.

2. LITERATURE REVIEW

Chi-Chuan Wang et al. [1] reviewed Flow visualization of annular and delta winglet vortex generators in fin-and-tube heat exchanger application. This study presented flow visualization and frictional results of enlarged fin-and-tube heat exchangers with and without vortex generators. Two types of vortex generators and plain fin geometry examined in this study. The vortex generators investigated in this study are the annular winglet and the delta winglet. Tests are performed in a water tunnel by utilizing dye-injection technique.

Z.X.YuanQ.Tao X. and T.Yan [2] investigated experimental Study on Heat Transfer in Ducts with Winglet Disturbances. They find Heat transfer and friction characteristics for a new type of enhanced rectangular duct with winglets have been investigated experimentally. The results indicate that, in the range of Reynolds number from 5 × 103 to 4.7 × 104, heat transfer performance of the enhanced duct with winglets is superior to the enhanced duct with transverse disturbances.

Jalal M. Jalil, et al. [3] studied the experimental investigation of the flow and heat transfer around a heated cylinder in cross flow with and without using winglets has been carried out. Distribution of the static pressure coefficients and Nusselt number and knowledge of the flow processes around the cylinder without winglets enable as to form an idea of the mechanism and pattern of the flow around the cylinder with winglets. They find (1) Winglets accelerate the flow to sweep the heat from high heated region on cylinder surface. (2) Heat transfer is enhanced by about 14% and Pressure drop is increased only slightly. (3)Heat transfer increases with increasing angle of attack. Heat transfer increases with increasing Reynolds number. (4)The trapezoidal winglet is the optimum type for enhanced heat transfer.

Balvinder Budania and Harshdeep Shergill [4] presented simulation of flow structure and heat transfer enhancement in a triangular duct with rectangular wing. They found the use of the rectangular wing also provide additional heat transfer enhancement on extended surfaces, the average local heat flux also increased with increase in the angle of attach of the rectangular wing and the pressure loss and friction factor also increased with increase in angle of attack.

M. Mirzaei and A. Sohankar [5] conducted heat transfer augmentation in plate finned tube heat exchangers with vortex generators a comparison of round and flat tubes. They studied Grid study and validation, flow structure-comparison of round and flat tube and found the vortex generator creates a stronger vortex with higher heat transfer for flat tube than the round one.

Hung-Yi Li, et al. [6] conducted both experiments and simulations are performed to investigate the thermal-fluid characteristics of a flat-fin heat sink with a pair of vortex generators installed in a cross flow channel. They found at low Reynolds numbers vortex generators increases the enhancement of the heat transfer of the heat sink and reduce the increase in pressure difference, thermalresistance increases with the angle of attack of the vortex generators and the pressure difference also increases.

Ya-Ling He, et al. [7] Analysis of heat transfer and pressure drop for fin-and-tube heat exchangers with rectangular winglet-type vortex generators. They analyzed influence of the angle of attack, influence of the number of rectangular winglet pairs (RWPs) and influence of the arrangement of RWPs. They found the longitudinal vortices generated by RWPs rearrange the temperature distribution and the flow field, and as a consequence significantly enhance the heat transfer performance of the fin-and-tube heat exchanger and compared with the baseline case; the heat transfer coefficient of the fin-and-tube heat exchanger is improved.

A.A. Gholami, Mazlan.A.Wahid and H.A.Mohammed [8] studied heat transfer enhancement and pressure drop for fin-and-tube compact heat exchangers with wavy rectangular winglet-type vortex generators. The effects of using the wavy rectangular winglet, conventional rectangular winglet configuration and without winglet as baseline configuration, on the heat transfer characteristics and flow structure are studied and analyzed in detail for the inline tube arrangements. They found heat transfer enhancement and pressure loss

penalty for fin-and-tube compact heat exchangers with the wavy-up and wavy-down rectangular winglets as special forms of winglet are numerically investigated in a relatively low Reynolds number flow.
S. Caliskan [9] studied experimental investigation of heat transfer in a channel with new winglet-type vortex generators. They study validation of smooth channel and effects of attack angle and vortex geometry. Found the both new punched triangular vortex generators (PTVGs) and punched rectangular vortex generators (PRVGs) arrangements had significantly enhanced the heat transfer rate, in comparison to a smooth duct, the averaged heat transferred from surfaces with PTVGs was higher than that of the PRVGs.
Boris Delac, et al. [10] studied numerical investigation of heat transfer enhancement in a fin and tube heat exchanger using vortex generators. Their research included Mathematical model, Numerical solution, Heat transfer improvement using longitudinal vortex generators. They concluded model (3D) has been successfully used to analyse optimal rectangular winglet vortex generator geometry regarding winglet height and attack angle

Nomenclature

A_s	Surface area (m^2)
A_c	Cross sectional area of triangular duct (m^2)
C_p	Specific heat at constant pressure (J/kg)
AR	Aspect Ratio
D_h	Hydraulic Diameter (m)
D_o	Diameter of orifice (m)
h	Average convective heat transfer coefficient (W/m2)
k	Thermal conductivity (W/m^0C)
L	Channel length (m)
$\dot{m}$	Mass flow rate of air (kg/s)
Nu	Nusselt number
P_r	Prandtl number
Re	Reynolds number
f	Friction factor
Δp	Pressure drop along length of tube (N/m2)
T_s	Average surface temperature (^0C)
T_{bm}	Bulk mean temperature (^0C)
T_i	Inlet temperature (^0C)
To	Outlet temperature (^0C)

Q_t	Total heat generated (W)
Q_1	Actual heat supplied (W)
Q_2	Heat absorbed by the fluid (W)
Q_L	Heat loss (W)
V_s	Velocity of air (m/s)

3. MATHEMATICAL FORMULATION

From the experimental data at different Reynolds numbers to calculate the different Nusselt number and Friction factor. Equations used for calculation of parameters are listed below.
The mass flow rate of air is calculated by following equation,
$\dot{m} = \rho Ac Va$

Where ρ is the density of air, Ac is the cross sectional area, Va is the velocity of air.
In the test section velocity of air is calculated by following equation

$$\mathrm{Va} = \frac{m}{\rho Ac}$$

Where ρ is obtained from bulk mean temperature.
The total heat generated by the heater is calculated as,

$$Q_T = V_v \, I$$

Where is voltage and I is current,
The actual heat supplied Q1 is calculated as,

$$Q_T = Q_1 + Q_L$$
$$Q_1 = Q_T - Q_L$$

Where heat loss is based on insulation and is obtained by measuring average wall temperature and the ambient temperature.
The heat absorbed by the air is calculated as,

$$Q_2 = \dot{m} C_p (T_o - T_i)$$

The average heat transfer coefficient is calculated as

$$Q_1 = h A_S \, (T_s - T_{bm})$$

The average Nusselt number is calculated as

$$\mathrm{Nu} = \frac{h\,Di}{k}$$

The friction factor is obtained as

$$f = \frac{\Delta p \; 2D_i}{V2\rho}$$

The Reynolds number is obtained as

$$Re = \frac{\rho V D_i}{\mu}$$

Where μ is dynamic viscosity of fluid.
Prandtl number is given as

$$Pr = \frac{\mu \, C_p}{k}$$

4. EXPERIMENTAL SETUP

The heat transfer experiments were conducted in an open triangular channel / duct and with rectangular wing. The experimental system consisted of a test section, an entrance section, an outlet section, U-tube manometer, temperature indicator and blower. The test section is 700 mm long and it is insulated with glass wool for avoiding heat transfer outside of channel. The triangular channel cross section dimensions is 60 mm base and 52 mm height. The length of inlet channel is 480 mm long and outlet channel is 250 mm long. The channel was constructed in mild steel material. The inlet section with orifice meter for measuring mass flow rate of air. The 12 numbers thermocouple are used for measuring temperature out of which two thermocouple are used for inlet section and outlet section and remaining ten thermocouple are used for measuring surface temperature. The pressure drops in test section are measured with the help of U-tube manometer. The control panel which consist of ammeter, voltmeter, 12- channel digital temperature indicator.

The experiments are tested with different air flow rates for Reynolds number ranging from 4000 to 22,000. The heat flux is kept constant by adjusting the voltage regulator. During each test the experimental data is recorded after reaching to steady state. After steady state inlet, outlet, surface temperatures, pressure drop across test section and mass flow rate of air are recorded for the calculation of Nusselt number and friction factor.

Fig1. Experimental setup

5. RESULT & DISSCUSSION

Verification of experimental data of plain channel

The experimental Nusselt number and friction factor characteristics of plain channel are compared and verified. The Nusselt number and friction factor data obtained from current plain channel are validated with those from the proposed correlation by Dittus-Boelter for Nusselt number and correlation by Blasius for friction factor.

These correlations are given below-

Nusselt number correlation of Dittus-Boelter: $Nu=0.023\ Re^{0.8}\ Pr^{0.4}$

Friction Factor correlation of Blasius:

$f = 0.316\ Re^{0.8}\ Pr^{0.4}$

The heat transfer characteristics are shown in figure 2

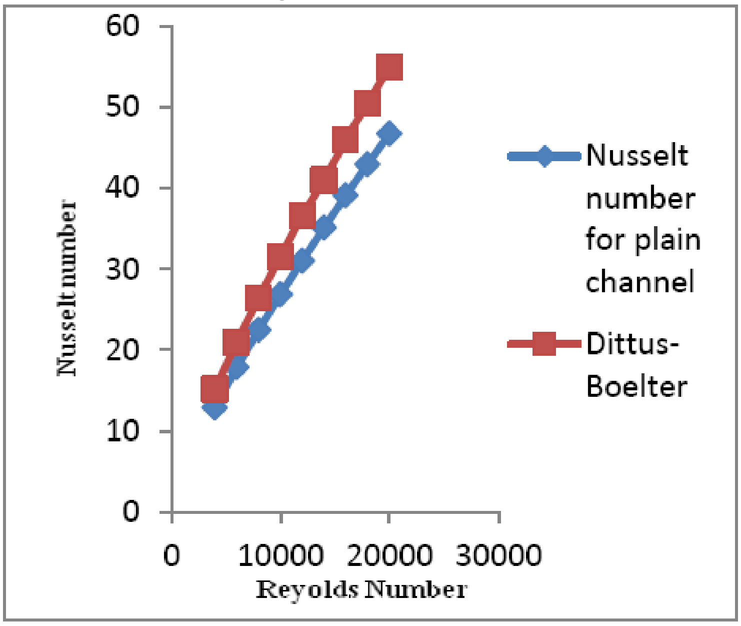

Fig. 2 Validation of Nusselt number

From above fig. Shows that Nusselt number increases with increase in Reynolds number.

The Friction factor characteristics are shown in figure 3.

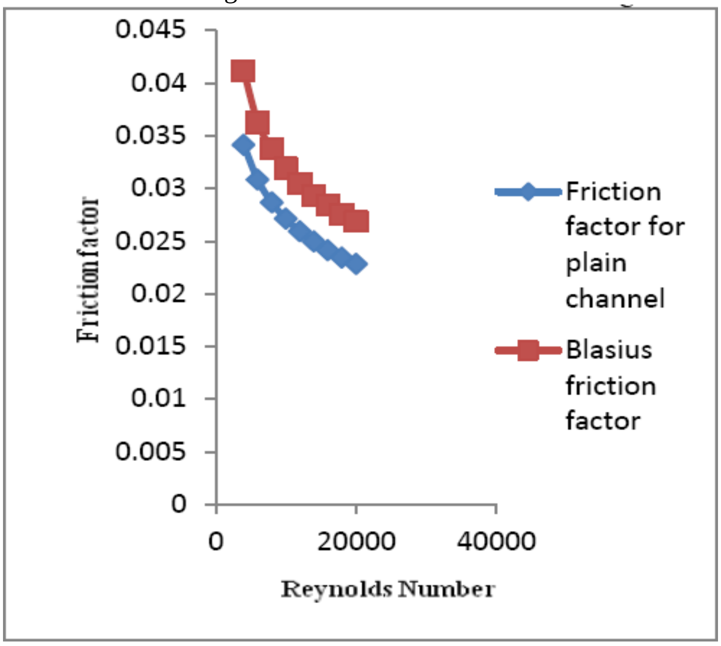

Fig. 3 Validation of friction factor

As seen above figure it is the nusselt number increase with increase with Reynolds number but friction factor decreases with increase with Reynolds numbers.

6. CONCLUSION

The friction factor and Nusselt number characteristics are investigated experimentally for smooth tube. The result shows that the experimental Nusselt number is ±20% than that of the Dittus-Boelter correlation and friction factor of smooth tube is ±12% than that of the friction factor obtained from Blasius correlation.

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